EXTRACTS

FROM

NARRATIVE REPORTS

OF THE

Survey of India

FOR THE SEASON

1901-02.

PREPARED UNDER THE DIRECTION OF

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TRIANGULATION IN UPPER BURMA.

Extract from the Narrative Report of Captain H. Wood, R.E., in charge No. 24 Party (Triangulation), Season 1901-02.

The programme of the party was to complete the triangulation of the Manipur Minor Meridional Series by joining on to two stations of the Burma Coast Series.

As the proposed line passed through an uninhabited tract of country and great difficulty had been experienced in previous years in obtaining sufficient coolies for transport purposes, arrangements had been made during the recess with a Bhamo contractor to supply Chinese mules at the same rate as he had charged the section of the party the previous season, when working in Bhamo district. When the party reached Pakôkku, mules to the number of 120 had already arrived and during the season they were of the greatest use, in fact it is extremely doubtful whether the work would have been completed if other transport had been used.

After a halt of two days Mr. Morton left to continue his previous year's work of reconnoitering in advance and selecting stations. He experienced very little difficulty until it became necessary to bend the series in a south-westerly direction to effect a junction with the Coast series. The Kyaukpyu Yomas which had to be crossed, and which at that point are practically uninhabited and unknown, with no paths of any kind except the tracks of wild elephants and with the entire country covered with a dense and almost impenetrable growth of bamboos, proved a formidable obstacle.

He succeeded eventually in cutting a path to one of the hills he had selected and built a station there, but as so much time had been occupied in the process and a delay for nearly three weeks had already been forced on the observer, and as the season was getting advanced with the almost certain prospect of haze stopping the work in a short time, it was considered advisable by cutting out one of the proposed stations to join up the series to the principal work by 3 triangles instead of a tetragon and 1 triangle as originally intended. This increased the distance between the stations somewhat, but as it is very improbable that this country will ever be surveyed, except on a small scale, this disadvantage is not very material.

Messrs. Bond and Hunter were employed in building the stations. Observations were not begun until December 2nd, as one of the lamp squads, with its escort had to march over 200 miles. A delay of over a week was also incurred at the first station owing to one of the advance stations, which had been selected the previous season when the haze was very thick and the features of the country almost indistinguishable, not being visible. The officer in charge of the building operations was not able to verify the line, owing to bad weather, until December 2nd, when he commenced to build on another hill.

The work proceeded fairly rapidly till the middle of January when the observations were again delayed for nearly 3 weeks, waiting for the completion of the stations on the Yomas; but once these were ready the triangulation was soon finished; the weather remaining fit for observing until the end of March. Unfortunately the assistant, who was reconnoitering, mistook the hill on which one of the stations of the Coast series was situated and when the observer arrived at the station he found the ray to the final station to be a very badly grazing one. Owing to the inaccessibility of the station it would have taken nearly six weeks to recast the triangulation with the almost certain result of the work being stopped before the completion of the series, so the ray was accepted.

Triangulation was finished on 8th March. During the later part of the season two of the members of the party were employed in rebuilding some of the stations of the Coast series as on inspection most of them were found entirely destroyed. The stations rebuilt were Yindaung (Rongdong) H. S., Ingyintaung

(Angrantong) H.S., Natkantaung (Nahkandong) H.S., Retkamauktaung (Rànkamao) H.S., Rwataung (Roadong) H.S., Dattaung (Thettong) H.S., Myaukpyadaung (Maopratong) H.S., and Kyeindawshin (Kindorong) H.S.

For the triangulation Messrs. Troughton and Simms' 12-inch Theodolite No. III was used, the method of observing being the same as that employed by Captain Turner on principal work during the previous season and described in the narrative report of last year. 4 to 6 measures were taken on 4 zeros. The mean triangular error was much greater than that obtained during the two previous seasons. This result is due to the large errors in the first four triangles and the last triangle. The cause of the latter has already been mentioned and is undoubtedly due to the grazing ray. Those of the former are probably due to atmospheric causes. Some of the angles of these triangles were measured at the end of the previous season when the haze was very dense, and the lamps and helios barely visible through it and the smoke from the burning jungle while the remaining angles were measured at the beginning of the present season under absolutely different weather conditions, the air being full of moisture and observations continually being interfered with by passing clouds. The error deduced from the intermediate triangles compares very favourably with those of previous seasons.

Reciprocal vertical observations were again taken at all stations at night to lamps; but as the weather did not prevent helio observations by day they were not employed in the computations.

These observations have, however, been computed separately and the heights of the final stations (using this season's work) when computed by helios and lamps separately only differ by 12 feet in the mean.* This is over a length of nearly 150 miles.

*Station	Height by Helio.	Height by Lamp.	Diff.
	feet	feet	feet
Ingyintaung (Angrantong) H.S. .	1398·3	1385·5	12·8
Yindaung (Rongdong) H.S. .	1050·1	1038·7	11·4
Mean .	...	...	12·1

When it is remembered that only one set of observations on one night only were taken at each station to lamps, while two and often three sets were taken on usually two days to helios, the good result obtained from the lamps is remarkable, and the method of taking vertical observations at night seems worth investigating.

A table of results similar to that given last year is appended and also another showing the differences in the heights of all the stations of the series as obtained from lamp observations as compared with those from helios.

The closing error of the series is small, being 0″·186 in latitude, 0″·200 in longitude and 6″·137 in azimuth. The elements of the two closing stations as deduced by the Coast series and by the Minor series are given below:—

	Latitude.	Longitude.	Azimuth.	Height in feet.	Log. Distance in feet.
	° ′ ″	° ′ ″	° ′ ″		
Ingyintaung (Angrantong) H.S. (Coast series).	19 57 31·915	93 43 0·578	125 20 28·059	1,379·4	...
Ditto (Minor series)	32·089	0·761	34·190	1,398·5	...
Yindaung (Rongdong) H.S. . (Coast series).	20 9 44·917	93 24 44·469	305 14 12·073	1,031·0	5·1072161
Ditto (Minor series) .	45·116	44·686	18·217	1,050·3	5·1072122

In addition to the stations the positions of a large number of peaks were fixed by intersections from different stations and a pillar was built on Shinmataung hill near Pakôkku and its position determined for the use of No. 7 Party.

Magnetic observations were taken at all the stations with a declinatorium by Bamberg and an area of about 1,000 square miles of hitherto unsurveyed country was sketched on the ¼-inch scale by the officer in charge.

The season's outturn of work was as follows:—

Number of stations newly fixed	10
Length of series completed in miles	148
Area of triangulation in square miles	2,800

The mean triangular error was 1″·62.

The health of the party, considering the evil reputation of the country worked through, was on the whole good. The men stationed with lamp squads on the Kyaukpyu Yomas suffered a good deal from fever and the greater part of the menial establishment was laid up at one time or another during the earlier portion of the season while working in the Yaw valley. Two men died, one from pneumonia, before the party took the field, contracted probably on board ship coming from Calcutta to Rangoon and the other from malaria at his station of the Yomas.

H. WOOD, Capt., R.E.

TABLE SHOWING HEIGHTS OF STATIONS OF MANIPUR MINOR MERIDIONAL SERIES AS COMPUTED BY HELIOS AND LAMPS.

Station.	Height.		Difference H—L.	Remarks.
	Helio.	Lamps.		
Khambiching h. s.	5739·9	...	...	Emanating stations
Tamunja h. s.	3387·3	...	...	
Narum h. s.	⊗3621·2	O3621·6	−0·4	
Phaitung h. s.	3675·3	O3674·0	+1·3	
Laiching h. s.	2228·6	O2232·2	−3·6	
Pagantaung h. s.	3083·6	O3084·1	−0·5	
Lungpolching h. s.	⊗5806·8	O5807·0	−0·2	
Alantaung h. s.	2149·5	O2152·2	−2·7	
Belmul h. s.	⊗6170·6	O6172·5	−1·9	
Mantaung h. s.	3220·0	O3225·9	−5·9	
Mwetaung h. s.	3403·0	O3402·9	+0·1	
Noepeji h. s.	2777·6	O2786·3	−9·7	Height for lamp deduced from one observation only.
Vownalumol h. s.	5420·9	O5438·3	−17·4	Closing stations of first season's work.
Kyettayahtaung h. s.	⊗3395·4	O3413·3	−17·9	
Waibula h. s.	⊗5952·4	O5968·8	−16·4	
Kyettaung h. s.	⊗4305·0	4322·2	−17·2	Height for lamp deduced from one observation only.
Wonelonetaung h. s.	4931·2	4948·0	−16·8	No helio observations taken. Height derived from lamp observations.
Kyanetaung h. s.	⊗4467·4	4487·7	−20·3	
Kyoukpyutaung h. s.	⊗2588·9	2605·4	−16·5	
Hlaingmataung h. s.	⊗4284·8	4302·9	−18·1	
Pya Nattaung h. s.	⊗1864·2	1880·7	−16·5	
Khantaung h. s.	⊗2653·7	2669·6	−15·9	
Ponyataung h. s.	⊗3636·4	3652·4	−16·0	
Tahynintaung h. s.	2600·1	O2610·6	−10·5	Closing stations of second season—lamp heights deduced from observations from one station only.
Pushumtaung h. s.	O6311·6	O6331·1	−19·5	
Pontaung h. s.	O2012·9	2022·5	−9·6	
Wumbataung h. s.	O7948·3	7959·1	−10·8	
Dudawtaung h. s.	2677·5	2685·2	−7·7	
Taungdaw h. s.	O3194·1	3202·5	−8·4	
Yinkwetung h. s.	5932·0	5933·2	−1·2	
Nwamataung h. s.	2010·7	2014·9	−4·2	
Sûntaung h. s.	6549·4	6556·0	−6·6	
Yeopungtaung h. s.	2841·5	2845·3	−3·8	
Augrantong h. s.	1398·5	1402·0	−3·5	Closing stations principal heights. 1379·4
Rongdong h. s.	O1050·3	1055·3	−5·0	1031·0

⊗ Signifies that lamp observations were used in part to deduce height at station marked.

O Signifies that observations were taken at one station only, *i.e.*, reciprocal observations were not taken at one or more of stations used to deduce height.

Table showing heights of Stations of Manipur Minor Meridional Series observed during season 1901-02 as computed from Helio and Lamp observations.

		Difference of height between Stations (B−A) obtained from observations to — Helio.	Lamp.	Height of B above sea-level from observations to — Helio.	Lamp.	Difference between values of difference of height between stations, *i.e.*, columns 2—3.	$\frac{r''}{c''}$ from — Helio.	Lamp.	Remarks.
	1	2	3	4	5	6	7	8	
A	Ta-hyhin-taung h. s.	...	...	...	...	...	...	...	
B	Pontaung h. s.	−587·5	−587·6	2012·6	2012·5	−0·1	·062	·102	In columns 4 and 5 the heights are given as deduced from helio and lamp. The values thus obtained being carried right through.
A	Pushumtaung h. s.	...	...	...	...	...	...	...	
B	Pontaung h. s.	−4298·4	−4309·1	2013·2	2002·5	−10·7	Reciprocal not observed from Pontaung.	·079	
	Means	...	...	2012·9	2007·5	...	...	...	
A	Pushumtaung h. s.	...	...	...	...	...	...	...	
B	Wumbataung h. s.	+1639·3	+1629·5	7950·9	7941·1	+9·8	Reciprocal not observed from Pushumtaung.	·062	
A	Pontaung h. s.	...	...	...	...	...	...	...	
B	Wumbataung h. s.	+5932·8	+5935·1	7945·7	7942·6	−2·3	·084	·088	
	Means	...	...	7948·3	7941·9	...	...	...	
A	Pontaung h. s.	...	...	...	...	...	...	...	
B	Dudawtaung h. s.	+663·4	+662·1	2676·3	2669·6	+1·3	·063	·110	Column 6 shows the individual differences between observations made by day and by night. Only 2 collimated angles were observed at night while at least 4 were made to helios, and at most stations these sets were repeated on one or two subsequent days.
A	Wumbataung h. s.	...	...	...	...	...	...	...	
B	Dudawtaung h. s.	−5269·6	−5273·4	2678·7	2668·5	−3·8	·082	·094	
	Means	...	...	2677·5	2669·1	...	...	...	
A	Dudawtaung h. s.	...	...	...	...	...	...	...	
B	Taungdaw h. s.	+515·1	+516·3	3192·6	3185·4	−1·2	·069	·086	
A	Wumbataung h. s.	...	...	...	...	...	...	...	
B	Taungdaw h. s.	−4752·7	−4755·5	3195·6	3186·4	−2·8	Reciprocal observation not taken from Taungdaw.	·078	
	Means	...	...	3194·1	3185·9	...	...	...	
A	Yaungdaw h. s.	...	...	...	...	...	...	...	
B	Yinkwetaung h. s.	+2739·3	+2740·9	5933·4	5926·8	−1·6	·064	·068	
A	Wumbataung h. s.	...	...	...	...	...	...	...	
B	Yinkewetaung h. s.	−2018·5	−2036·2	5929·8	5905·7	−17·7	·063	·078	
	Means	...	...	5931·6	5916·3	...	...	...	
A	Taungdaw h. s.	...	...	...	...	...	...	...	
B	Nwamataung h. s.	−1181·4	−1184·0	2012·7	2001·9	−2·6	·064	·075	
A	Yinkwetaung h. s.	...	...	...	...	...	...	...	
B	Nwamataung h. s.	−3922·2	−3927·0	2009·4	1989·3	−4·8	·067	·076	
A	Dudawtaung h. s.	...	...	...	...	...	...	...	
B	Nwamataung h. s.	−667·5	−665·2	2010·0	2003·9	+2·3	·062	·101	
	Means	...	...	2010·7	1998·4	...	...	...	
A	Yinkwetaung h. s.	...	...	...	...	...	...	...	
B	Suntaung h. s.	+615·4	+622·4	6547·0	6538·7	−7·0	·061	·071	
A	Nwamataung h. s.	...	...	...	...	...	...	...	
B	Suntaung h. s.	+4540·7	+4541·6	6551·4	6540·0	−0·9	·061	·070	
	Means	...	...	6549·2	6539·4	...	...	...	
A	Yinkwetaung h. s.	...	...	...	...	...	...	...	
B	Yeopungtaung h. s.	−3091·7	−3091·0	2839·9	2825·3	+0·7	·062	·069	
A	Suntaung h. s.	...	...	...	...	...	...	...	
B	Yeopungtaung h. s.	−3706·8	−3707·6	2842·4	2831·8	−0·8	·064	·073	
	Means	...	...	2841·2	2828·6	...	...	...	

TABLE SHOWING HEIGHTS OF STATIONS OF MANIPUR MINOR MERIDIONAL SERIES OBSERVED DURING SEASON 1901-02 AS COMPUTED FROM HELIO AND LAMP OBSERVATIONS—*continued.*

		Difference of height between Stations (B—A) obtained from observations to		Height of B above Sea-level from observations to		Difference between values of difference of height between stations, *i.e.*, columns 2—3.	$\frac{r''}{c''}$ from		Remarks.
		Helio.	Lamp.	Helio.	Lamp.		Helio.	Lamp.	
	1	2	3	4	5	6	7	8	9
A	Suntaung h. s.	...	...	...	...	...	...	...	
B	Angrantong h. s.	−5152·0	−5156·9	1397·2	1382·5	−4·9	·066	·074	
A	Yeopungtaung h. s.	...	...	...	...	...	...	...	
B	Angrantong h. s.	−1441·8	−1440·5	1399·4	1388·1	+1·3	·066	·083	
	MEANS	...	...	1398·3	1385·3	...	...	...	
A	Yeopungtaung h. s.	...	...	...	...	...	...	...	
B	Rongdong h. s.	−1792·4	−1789·3	1048·8	1039·3	+3·1	Reciprocal observation not taken from Yeopungtaung.	·088	
A	Angrantong h. s.	...	...	...	...	...	...	...	
B	Rongdong h. s.	−346·9	−347·3	1051·4	1038·0	−0·4	·066	·083	
	MEANS	...	...	1050·1	1038·7	...	...	...	

II

LATITUDE OPERATIONS FOR THE YEAR 1901-02.

Extract from the Narrative Report of Lieutenant H. McCally Cowie, R.E., in charge Nos. 22 and 23 Parties (Astronomical), Season 1901-02.

Introductory.

There being only one officer available, during the field season of 1901-02. Nos. 22 and 23 Parties were combined and employed in taking observations for latitude at stations on the Calcutta Meridional Series and the Darjeeling Triangulation.

The combined parties arrived on November 18th at Madhupur G. T. S. of the Calcutta Meridional, the most southerly point at which observations were taken. From here the parties worked northwards, determining the latitudes of Charaldánga, Chanduria and Lohágara, all of the above-mentioned series. The next stations visited were Jalpaiguri and old Siliguri and later, Kurseong, Senchal, Tonglu and Phallut of the Darjeeling Triangulation.

The changes of conditions experienced in the field were very great. For the first part of the season, the party worked and marched in flat or gently undulating country, with a daily range of temperature of from about 88° F. to about 56° F. The last six weeks were spent in the outer Himalayas, all but a few days being passed on heights between 8,000 and 12,000 feet above mean sea level, where the temperature fell to below freezing point, five nights in the seven, and snow and high winds added to the difficulties of climbing steep and rough paths.

The conditions under which the observations were taken, were unfavourable. While in Bengal, low lying mists, thick and damp, formed every night, preventing clear vision and introducing discomfort and consequent irritation, where, in especial, tranquillity is desirable.

In the latter part of the season, clouds interfered very much with the progress of the work and it was impossible, without an undue expenditure of time and labour, to get results from more than some ten pairs of stars.

At the station on Phallut work was delayed for several days by a severe storm of wind and snow, which set in a few hours after the arrival of the party. On its termination, the observatory tent had to be pitched in over a foot of snow and in a temperature of 21° F.

In spite of these somewhat trying circumstances, the health of the party was good.

Final Results and Discussions on the values of O—C.

2. The final results of the season's observations are tabulated below in Table I :—

TABLE I.

1 STATIONS	2 Heights above mean sea level.	3 Longitude.	4 Geodetic Latitude =C	5 Astronomical Latitude =O	6 Probable Error of Astronomical Latitude.	7 O—C
		CALCUTTA MERIDIONAL SERIES.				
	Ft.	° ′	° ′ ″	° ′ ″	″	″
Madhupur . . .	92	88 32	23 56 38·97	23 56 42·82	±0·040	+3·85
Charaldánga . .	149	88 26	24 52 43·95	24 52 45·36	±0·051	+1·41
Chanduria . . .	160	88 25	25 44 27·47	25 44 31·93	±0·058	+4·46
Lohágara . . .	205	88 24	26 2 12·04	26 2 14·19	±0·057	+2·15
Jalpaiguri . . .	300 Apprx.	88 47	26 31 15·13	26 31 9·16	±0·056	−5·97
Siliguri . . .	401	88 27	26 41 41·11	26 41 18·10	±0·080	−23·01

TABLE I.

1 STATIONS.	2 Heights above mean sea level.	3 Longitude.	4 Geodetic Latitude —C	5 Astronomical Latitude —O	6 Probable Error of Astronomical Latitude.	7 O—C
		DARJEELING TRIANGULATION.				
	Ft.	° ′	° ′ ″	° ′ ″	″	″
Kurseong . . .	4,428	88 18	26 52 6·16	26 51 15·05	±0·060	−51·11
Senchal . . .	8,600	88 20	26 59 8·78	26 58 32·98	±0·091	−35·80
Tonglu . . .	10,073	88 7	27 1 53·54	27 1 11·30	±0·096	−42·24
Phallut . . .	11,815	88 3	27 12 42·51	27 12 5·28	±0·073	−37·23

These results show that the quantity O—C preserves its positive character to a point very much further north than we are led to expect from a comparison of the positions of stations on this meridian of 88° E., relatively to the Himalayas. with those of stations on the $77\frac{1}{2}$° E. meridian and the deflections of the plumb-line found at the latter.

The sign of O—C does not change till a north latitude of about 26° 10′ is reached a point from which the Himalayas are visible.

A noticeable feature of the deflections north of this point is the rapid rise of the negative values between Jalpaiguri and Kurseong, the increase being 45″ in a difference of 20′ in latitude.

The value found at Kurseong is the largest negative yet met with, though that revealed at Rajpur is only 3″ less.

In the following Table are given:—

(1) In column 7, the approximate values, which O—C should have on the 88° meridian, mountains and ocean being uncompensated. (These figures have not been calculated, but have been estimated from those given in Professional Paper No. 5, "the attraction of the Himalaya mountains upon the plumb-line in India)."

(2) In column 9, the approximate values which O—C should have on the 88° meridian, deduced from those actually found on the $77\frac{1}{2}$° meridian.

(3) In column 11, the values of O—C on the assumption of the main Himalayan masses being compensated to the extent of two-thirds and the existence of an east to west chain of density (also estimated from the figure given on page 110—114 of Professional Paper No. 5).

(4) The discrepancies apparent in each case between actual and estimated values.

TABLE II.

On the 88° Meridian			On the 77° 30′ Meridian			O—C estimated for "no compensation"		O—C deduced from those on 77½ meridian		O—C for ⅔ compensation with chain	
Station 1	Latitude 2	O—C 3	Station 4	Latitude 5	O—C 6	O—C 7	Discrepancy 8	O—C 9	Discrepancy 10	O—C 11	Discrepancy 12
	° ′	″		° ′	″	″	″	″	″	″	″
Kurseong	26 52	−51				−39	−12				
			Rajpur	30 24	−48						
Siliguri	26 41	−23	Dehra Dún	30 19	−38	−35	+12	−39	+16	−33	+10
Jalpaiguri	26 31	− 6				−30	+24	−30	+24	−28	+22
			Nojli	29 53	−14						
Lohágara	26 2	+ 2				−15	+17	−11	+13	−13	+15
			Kaliána	29 31	− 7						
Chanduria	25 44	+ 4				− 9	+13	− 8	+12	− 7	+11
			Datairi	28 44	− 6						
Charaldánga	24 53	+ 1	Bostán	28 31	− 6	− 4	+ 5	− 6	+ 7	− 4	+ 5
			Chandaos	28 5	− 1						
			Noh	27 51	0						
Madhupur	23 57	+ 4				− 1	+ 5	− 5	+ 9	− 1	+ 5

Taking the figures of columns 7 and 8, based on the assumption of "no compensation," it might be thought the discrepancies could be explained by supposing, either that the deflection at Kaliánpur is normal and that there is at each station on the 88° meridian, a disturbing influence, tending to draw the plumb-line southwards, or that the plumb-line at Kaliánpur has an abnormal deflection to the north, while at longitude 88° E. the deflections are generally normal. Taking the first case, it would appear that the centre of the source of the disturbing influence, over which there should be no effect, lies south of Madhupur, in fact, south of Calcutta, since Calcutta also shows a positive deflection, where O—C might be expected to have a negative value.

And the effect of this southern attraction seems to attain a maximum of at least + 24″ at Jalpaiguri, at a distance of about 300 miles from the centre of the source.

This disturbing element would appear, then, to be, in power and range so enormous as to render the fact of its existence improbable and difficult to accept. Besides which, if its effect at Jalpaiguri is + 24″ south, how is it that in the next 12 miles northwards it has dwindled to + 12″ south and in the next 24 miles we find an abnormally large northern deflection?

The character of deflections, theoretically, is a comparatively rapid rise in value from the point of no influence, over the source of attraction, to that of the maximum and again a slower fall to the vanishing point.

To explain these results it would be necessary to assume another large abnormal influence to the north, acting in conjunction with normal Himalayan and oceanic attractions.

Evidently, then, the supposition of a large southern attraction in the north-east of India, with normal deflection at Kaliánpur, instead of explaining discrepancies, only increases the difficulties of the question, that is, if we start with the assumption of "no compensation."

If we take the second case, an abnormal deflection at Kaliánpur, we are at once faced by the difficulty of explaining high negative deflections elsewhere in India.

The northern extremity of the Great Arc must be, then, under the influence of a northern disturbing force. Kurseong likewise must be affected by a large northerly attraction. The deflections over the North-Western Quadrilateral, generally, must also be disturbed by abnormal attractions.

If at Kurseong, there is a large northern influence, how is it that its effect vanishes so rapidly to southwards?

On a basis of "no compensation" the deflections on the 88° meridian are very difficult to explain satisfactorily.

If we work on the hypothesis that the Tibetan plateau is compensated to the extent of two-thirds and that running across India, from west to east, there is an underground chain of excessive density, as suggested in Professional Paper No. 5, we ought to find deflections approximately of the values given in Column 11.

Here again the discrepancies are all positive sign, indicating, either that the chain by the time it reaches the 88° meridian, has attained enormous power and dimensions; in fact, has pushed out its point of maximum influence from 200 to 300 miles from the centre and has increased its maximum effect by 22,″ or that the Himalayan masses are compensated to a greater degree than two-thirds. For the same reasons as before, as in the case of "no compensation," this large southern influence is difficult to accept and will lead to further difficulties.

If we take the other alternative, that the Himalayan masses are compensated, that they exert no influence on the plumb-line in the plains, how can the Kurseong deflection be explained? Is it possible that local masses can exist, which are capable of producing this large northerly disturbance and yet have no effect 20 miles south?

The visible masses within two miles of Kurseong would warrant a deflection of only 2″ north.

Whichever assumption we start from "no compensation", "complete compensation" or "complete compensation with a dense southern chain," it appears we must conclude a large abnormal northern influence at Kurseong.

If we grant this, the simplest explanation of the deflections on the meridian to the south, is that the Himalayan masses are completely compensated.

From this it would follow that the deflections at the northern extremity of the Great Arc are abnormal, that is, that they are due to other sources of attraction than the high plateaux of the interior in Tibet.

3. It is difficult, at the present time, to form any definite conclusions from the season's results, or to dogmatize in any way as to the general laws of Himalayan attraction: for our knowledge of outer Himalayan deflections rests practically on the values determined in two localities only, the northern extremity of the Great Arc and the Darjeeling Triangulation.

Numerous results have been obtained from stations in the Indian Peninsula and the Northern Indian Plains and the data available from most localities is fairly plentiful. Yet it is found that these extra Himalayan results, numerous as they are, are by themselves, inadequate for the solution of questions of Himalayan compensation or for the determination of even the range of Himalayan and oceanic influences.

Since the time of Archdeacon Pratt, we have extended our data immensely, yet the problems that he set himself to solve, still remains unanswered. It is evident that the nature of deflections in the Peninsula is very complex and the simultaneous determination of Himalayan, oceanic and local influences, most difficult. It seems possible that the last class of attraction masks most effectually, such effects as are purely Himalayan. Consequently, the further extension of data from the plains does not promise to give results proportionate to the labour and time involved. In the search for light on questions of the compensation of Himalayan masses, it would seem more profitable to work gradually towards such masses, as may be supposed to constitute the main sources of Himalayan attraction, traversing localities, where this influence, if it exist at all, should be the dominant factor in the deflecting of the plumb-line; where its effects should be too large to be obliterated by local disturbances.

At present there are only some seven values for the deflections on the outer Himalayas; and of these four are in one and same locality, while two more are close together in another. There seems to be need for more results from the outer hills up to the foot of the main masses. Even from sub-Himalayan regions, below the foot hills, the data is somewhat scanty and here again, is not sufficiently comprehensive but is grouped in two or three localities.

Observations taken on the outer ranges and as far into the interior as possible, would either corroborate as normal, the high values found on the 77½° and 88° meridians, the only two localities from which we have results, or would show them to be irregular and would tend to strengthen or rectify our ideas, at present somewhat indefinite of the proportion, the true significance of indications in the Peninsula.

Probable errors of observation and of stars' place.

4. Table III gives the probable errors of observation and of stars' place, deduced from the observation at each station and the average probable errors determined for the same quantities in 1900-01.

TABLE III.

1 STATION.	2 Probable Errors of result of unit weight	3 Probable Errors of observation	4 Probable Errors of stars' place
	"	"	"
Madhupur	±0·243	±0·257	±0·220
Charaldánga	±0·333	±0·286	±0·338
Chanduria	±0·339	±0·297	±0·274
Lohágara	±0·358	±0·326	±0·305
Jalpaiguri	±0·280	±0·295	±0·218
Siliguri	±0·329	±0·235	±0·368
Kurseong	±0·308	±0·321	±0·122
Senchal	±0·267	Indeterminate.	
Tonglu	±0·286	Indeterminate.	
Phallut	±0·212	Indeterminate.	
Mean	±0·296	±0·288	±0·264
Mean for 1900-01	±0·266	±0·28	±0·15

It is apparent that the probable errors of observation, that is of the quantity $\frac{1}{2}(Z_n - Z_s)$, has remained practically the same, while the probable errors of $\frac{1}{2}(\Delta_n + \Delta_s)$, the half sum of the stars' N. P. D.'s, has increased considerably.

In this connection, it is to be remembered that the probable error of observation is unaffected to any appreciable extent by an error in the adopted micrometer value, being determined from the differences existing between each individual value given by a pair of stars and mean for that pair. From the probable error of the mean colatitude, the probable error of observation and the number of observations on each pair, is deduced the probable error of the quantity $\frac{1}{2}(\Delta_n + \Delta_s)$. Consequently the burden of the errors caused by an incorrect micrometer constant is thrown on the star's place, the probable error of which, then, cannot be considered trustworthy.

An examination of the apparent errors in the adopted value for the micrometer, *vide* Table V will show at once, that the increase in the probable error of N. P. D. has occurred simultaneously with a rise of the error in the micrometer value.

In consequence of the change in the probable error of star's place, an independent determination of this quantity was made from the data given in the Catalogue of Fundamental Stars, by Newcomb, which had been used almost exclusively during the season.

This investigation, which involved 231 stars, gave, for the epoch 1902-03.

Average probable error of $\frac{1}{2}(\Delta_n + \Delta_s$ 0″·096) = ±
against 0″·264 ±

deduced from the latitude results, as given in Table III.

5. The system of relative weights used in the combining of mean results from each pair of stars has been calculated from the formula.

System of Combination Weights.

$$\sqrt{\frac{e^2}{xx} + \frac{e^2}{n}}$$

where p = relative weight,

$\frac{e_{xx}}{2}$ = probable error of $\frac{1}{2}(\Delta_n + \Delta_s)$, adopted = $\pm 0''\cdot 2$

e = probable error of $\frac{1}{2}(Z_n - Z_s)$, adopted = $\pm 0''\cdot 3$
n = number of times the pair has been observed.

Unit weight being given to the mean result from one pair of stars observed twice.

In the case of compound pairs formed from three stars, the result from each component has been given two-third weight of a similiar result from a single pair.

6. Examining the results of the previous season 1900-01, we find that a probable error of $\pm 0''\cdot 05$ should be given by observations on about 44 stars, each pair being observed twice.

But on looking over the results for 1901-02, where the probable error of observation is almost exactly the same as that of the season before, we see that observations to 80 and 90 stars have failed to reduce the probable error to $\pm 0''\cdot 05$.

The same star catalogue was used in both seasons and we cannot attribute this change of the degree of precision to the probable error of catalogue.

It seems evident, that in 1901-02, there have been introduced errors, other than those of observation and star catalogue, which did not appear, at any rate to the same extent, in the work of 1900-01, errors, which we must then conclude to be of a systematic nature. Had they been purely accidental, their effect should have been apparent in the probable error of observation. We see, also, that these systematic errors are of a size to overwhelm the probable error of star's place. The probable error shewn at Jalpaiguri, where half the number of stars were observed four times, is very much the same as those found at other stations. In both cases, the number of observations was practically the same: at Jalpaiguri only half the usual number of stars was observed. The season's results show, that increasing the number of stars above 40 or 50, has had prac-

tically no effect in reducing the final probable error which has been dependent chiefly on the probable error of observation, and another class of error, apparently systematic.

The most probable source of these errors is, of course, an incorrect micrometer value and there is little room for doubt that such an error has largely influenced the season's final probable errors.

The probable error of star's place, being shown by the catalogue to be so small, there seems to be little use in increasing the number of stars observed above 40 to 50, until all systematic errors, due to an incorrect micrometer constant, can be removed. It requires only a very small error in the adopted micrometer value to introduce into the observations, error larger than the probable error of star's place.

But the probable error of catalogue and observation being $\pm 0''{\cdot}1$ and $\pm 0''{\cdot}3$ respectively, it seems we might, with advantage, increase the number of observations to each pair of stars to at least four.

7. In selecting stars for observation, Newcomb's Catalogue of Fundamental Stars was used almost exclusively.

Comparison of Newcomb's Catalogue for 1900 and the Greenwich Ten-year Catalogue for 1880.

The investigation made last season into the relative values given by Newcomb's Catalogue and the Greenwich Ten-year Catalogue for 1880, has been repeated this year, the result being shown in Table IV :—

TABLE IV.

Station.	Using Newcomb's Catalogue		Using Greenwich Catalogue		N—G in latitude
	Latitude=N.	Probable Error	Latitude=G	Probable Error	
	° ′ ″	″	° ′ ″	″	″
Madhupur	23 56 42·88	±0·048	23 56 42·50	±0·052	+0·38
Charaldánga . . .	24 52 45·36	±0·064	24 52 45·10	±0·057	+0·26
Chanduria	25 44 31·85	±0·073	25 44 31·54	±0·075	+0·31
Lohágara	26 2 14·08	±0·066	26 2 13·75	±0·059	+0·33
Jalpaiguri	26 31 9·08	±0·073	26 31 8·89	±0·078	+0·19
Siliguri	26 41 18·12	±0·109	26 41 18·09	±0·108	+0·03
Kurseong	26 51 15·23	±0·082	26 51 14·96	±0·075	+0·27
Mean	...	...	...	...	″ +0·25
Mean, 1900-01 . . .	...	...	...	...	+0·25

These values show that both catalogues give very much the same probable error, but the mean results differ by about $0''{\cdot}3$. The consistency of sign and amount of N—G is noteworthy.

8. The values of the instrumental constants were determined by the methods employed in previous years.

Micrometer constant.

In the case of the micrometer screw, the difference of zenith distance between two stars, differing only slightly in R. A. and declination, is measured by means of the micrometer, and this quantity, in terms of a revolution of the screw, equated to the apparent difference of declination. The value in seconds of arc for one revolution of the micrometer screw follows simply.

The mean value obtained from 47 observations on 30 different couples of stars and adopted in the computations was

$$\text{One revolution} = 69''{\cdot}127 \pm 0''{\cdot}002$$

On the conclusion of the computations for each station, a comparison of the mean colatitude, given by observations introducing positive micrometer corrections, with that from observations giving positive corrections, taking into consideration the mean negative and negative micrometer differences involved, showed the apparent error in the adopted micrometer constant.

The results of this investigation are given in column 3 of Table V.

TABLE V.

1 Stations	2 Micrometer value used in the computations	3 Apparent error shown by the Latitude results	4 Apparent corrected value
	For one revolution of screw.		
	"	"	"
Madhupur	69 127	+ 0· 017	69· 110
Charaldánga	...	+ 0· 019	69· 108
Chanduria	.	+ 0· 015	69· 112
Lohágara	...	+ 0· 025	69· 102
Jalpaiguri	...	+ 0 018	69 109
Siliguri	...	+ 0· 014	69· 113
Kurseong	...	+ 0· 005	69· 122
Senchal	...	+ 0· 023	69· 104
Tonglu	...	+ 0· 017	69· 110
Phallut	...	+ 0· 017	69· 110
Mean	69· 127	+ 0 017	69· 110
Mean, 1900-01	69· 120	− 0· 008	69· 128

The mean error is seen to be +0"·017 per revolution and the constancy among the different values, of sign and amount, is remarkable.

It should be stated that the value 69"·027 is the mean result of observation taken at different times during the season, from November 1901 till March 1902 and a consideration of the results obtained at each station, shews that it is highly improbable that this apparent error can be due to an actual change of focal setting.

The relative sizes of the apparent error deduced from the latitude results and the probable error given by the independent observations, do not allow of this difference, =0"·017, being considered an accidental error. It would seem to be due to some constant cause.

9. No explanation of this discrepancy between observed and deduced values was forthcoming till October 1902, when the micrometer screw was examined under "G" microscope of the Base-line equipment.

Examination of micrometer screw.

The micrometer was detached from the Zenith Telescope and placed under "G" microscope, firmly attached to one of the spare gunmetal "camels", by means of which the whole could be,

(1) raised or lowered till the movable wires became sharply focussed in "G" microscope.

(2) moved longitudinally in the direction of the micrometer screw.

"G" was so placed, that its micrometer screw was as nearly parallel, as could be judged, to that of the Zenith Telescope micrometer. It was assumed that this would be effected by turning "G", till its movable wires came parallel to the micrometer wire of the Zenith Telescope.

As only relative values were to be determined for each revolution of the screw, it was not necessary that the two screws should be absolutely parallel. All that was required, was to contrive that the directions of motion in both micrometers should so nearly coincide, that the same part of "G's" movable wire would always intersect the same part of the Zenith Telescope wire, to avoid as far as possible, errors due to either wire not being set at right angles to its micrometer screw and to imperfections in either wire.

The apparatus having been satisfactorily prepared, "G" microscope adjusted and the Zenith Telescope micrometer placed in position, and levelled, with its wires clearly focussed and illumined in "G" microscope, the observations were commenced, the procedure being as follows:—

"G" micrometer was set to a convenient reading about the centre of the field. The Zenith Telescope wire B was next set to a reading of 3100 and the

whole micrometer traversed by means of the "camel" screw, till B came into position between the two parallel intersecting wires in the field of "G". Several careful intersections on B were then taken with "G" micrometer and the mean reading of "G" computed. The Zenith Telescope micrometer was then set to read 3200 and again intersections were made with "G" and the mean reading deduced. The difference of the two means gave a value in terms of "G" for the revolution 3100 to 3200.

"G" micrometer was now set to its first reading—that for Zenith Telescope 3100 and the Zenith Telescope micrometer, remaining at a setting of 3200, was traversed by the "camel" screw, till B again came into position between "G's" intersecting wires.

Intersections were then made as before and the procedure repeated for the revolution 3200 to 3300. The portion of the Zenith Telescope screw between readings 3100 and 6900 was thus examined, revolution by revolution.

In this way, values for each revolution were obtained in terms of the same part of the screw of "G" microscope, thus avoiding errors due to irregularities in one standard.

One complete set of observations having been taken, the whole apparatus was dismantled—re-erected, the lighting changed and a second set of values determined.

The means of both set of results were then adopted as final values "for consideration."

The probable error of these mean quantities will be some indication of the power of "G" microscope to measure small errors of the screw and a guide as to how far the results of the observations may be trusted.

The observations show the probable error of one intersection and reading of "G" to be $= \pm 0{\cdot}33$ division of "G".

Hence the probable error of the means of six intersections and readings $= \pm 0{\cdot}13$ division.

Assuming the probable error of a setting of the Zenith Telescope micrometer to be— $\pm\, 0{\cdot}03$ division $= \pm\, 0{\cdot}07$ division of "G".

It can be calculated that the probable error of the quantities, shown in column 3 of Table VI is $\pm\, 0{\cdot}15$ division of "G".

The results of the observations were then plotted and a mean curve drawn, the differences existing between the observed values and those given by the curve being considered errors of observation.

Table VI gives the mean observed values, together with those taken from the curve and the difference between the two.

TABLE VI.

Revolutions of screw		Equivalent in terms of "G" microscope		Difference	Revolutions of screw		Equivalent in terms of "G" microscope		Difference
From	To	Actual	By mean curve		From	To	Actual	By mean curve	
1	2	3	4	5	1	2	3	4	5
3100	3200	241·87	241·80	+0·07	5000	5100	241·12	240·88	+0·24
3200	3300	1·67	1·64	+ ·03	5100	5200	0·61	0·92	− ·31
3300	3400	1·22	1·55	− ·33	5200	5300	1·58	1·20	+ ·38
3400	3500	0·54	1·48	− ·94	5300	5400	1·20	1·46	− ·26
3500	3600	2·58	1·42	+1·16	5400	5500	1·87	1·59	+0·28
3600	3700	1·81	1·42	+0·39	5500	5600	1·84	1·67	+ ·17
3700	3800	0·52	1·45	− ·93	5600	5700	1·14	1·71	− ·57
3800	3900	1·89	1·55	+ ·34	5700	5800	1·55	1·72	− ·17
3900	4000	1·31	1·60	− ·29	5800	5900	1·69	1·72	− ·03
4000	4100	2·14	1·61	+ ·53	5900	6000	2·26	1·70	+ ·56
4100	4200	0·85	1·59	− ·74	6000	6100	1·12	1·67	− ·55
4200	4300	1·82	1·57	+ ·25	6100	6200	1·83	1·64	+ ·19
4300	4400	1·15	1·50	− ·35	6200	6300	1·59	1·61	− ·02
4400	4500	1·80	1·42	+ ·38	6300	6400	1·48	1·57	− ·09
4500	4600	1·62	1·30	+ ·32	6400	6500	1·78	1·52	+ ·26
4600	4700	0·88	1·18	− ·30	6500	6600	1·79	1·46	+ ·33
4700	4800	1·32	1·07	+ ·25	6600	6700	1·20	1·39	− ·19
4800	4900	1·30	0·97	+ ·33	6700	6800	1·02	1·31	− ·29
4900	5000	0·66	0·89	− ·23	6800	6900	1·41	1·22	+ ·19
								Sums.	+6·65 −6·39

It will be noticed that 5000, at the centre of the comb, the point to which all micrometer readings are referred, lies very close to that part of the screw having the minimum value 240·88 divisions of "G". That, in consequence, on both sides of the 5000 point the values of the revolutions are increasing, till they reach on the one side, 241·72 divisions at about 5800, and on the other, 241·61 at a reading of about 4100.

Under these circumstances, in a difference of micrometer readings between two positions similarly situated within these limits, on opposite sides of 5000, the variations in the values of the revolutions do not tend to cancel, leaving us a difference in terms of the value of the screw at 5000.

In other words, for no portion of screw, situated half on one side, half on the other of 5000, does the mean value of a revolution correspond to the value at 5000; and besides this, the greater the length of screw involved between 4100 and 5800, the greater will be the mean revolution.

10. Now in observing couples of stars for the determination of the value, in seconds of arc, of a revolution of the micrometer screw, it has been customary to select and combine such stars, as will give a large difference of zenith distance, the only limit being the effection length of screw, with the object of minimizing the effects of errors of observation. The observations involved a micrometer difference of rarely less than 15, and frequently of as much as 55 revolutions or more. It will be found that the average micrometer difference is little short of 30 revolutions. (The mean given by last season's observations is 35) and supposing the readings to have been taken at points on opposite sides of, and at similar distances from 5000, the portion of screw brought into play in the mean observation will be that between readings of 3500 and 6500 divisions.

The curve gives this portion a mean value equivalent to 241·44 divisions of "G".

In the case of latitude observations, where the auxiliary micrometer wires A and C are utilized, (the intervals AB and BC are each approximately equal to 1,000 divisions) and when the working limit in the difference of zenith distances of the two stars of a pair is 50′ or about 43 revolutions, the mean number of revolutions actually used cannot be more than 14 or 15. The portion of screw involved is then between readings 4300 and 5700.

This bit of screw is shown by the curve to have a mean value of 241·27 divisions of "G".

We shall then find that the latitude observations and the independent observations tend to give values relatively proportional to 241·27 and 241·44. The difference is 0·17 division.

The mean value obtained for a revolution from independent observations during the season, was

$$69''\cdot127$$

and if we suppose this to correspond to 241·44 divisions of "G", the difference 0·17 division will represent 0″.049.

The latitude results would thus indicate an error of + 0″·049 in the adopted value of a revolution.

It seems probable that this may be an explanation of the difference between the deduced and independently observed values for the micrometer constant—a difference, which nearly always is quite out of proportion to the probable error of the observed value.

It seems to be due to the circumstance, that in the two different observations, that for the determination of the micrometer value and that for the determination of latitude, different portions of the screw have been involved.

If this is so—and it seems probable, the apparent errors given by the latitude results are indications of the correct micrometer value for that portion of screw utilized in the latitude observations, and the adoption of this corrected value for use in the final computations would appear justifiable.

The above investigation also shows the advantage, of so adjusting the micrometer, if the design of the instrument allows of it, that the point, by convention called 5000, indicated by the centre of the comb, shall be at such a place on the screw, that the errors of revolutions in the utilized length on the one side, are, as far as it is possible, balanced by the errors in the similar portion on the other side.

11. In consideration of the difference found between the mean results given by positive and negative micrometer corrections respectively, it should be remembered that, as regards observations which have necessitated the use of the auxiliary movable wires, A and C, in cases where the micrometer correction is positive, the value of the interval A—C will enter as a positive quantity, and where the correction is negative the interval will appear as negative in the computations. Consequently the effects of an error in the adopted value for the interval A—C on the mean results from observations giving positive and negative micrometer corrections respectively, will be of opposite signs, and errors due to other causes being eliminated, the difference between the two mean results will be a measure of the error in the A—C constant.

To form some idea of what the size of this error must be to produce a difference of, say, $+0''\cdot40$ between the mean results, C+ given by positive, and C— given by negative micrometer corrections respectively, let us assume N observations, half of which give positive and half negative corrections.

An analysis of observations has shown that about 50 per cent. involve the interval A—C. Then of the $\frac{N}{2}$ observations giving positive corrections, $\frac{N}{4}$ will ntroduce A—C positive in every case, and if the value of A—C be in error by $+x''$, the resulting error

$$\text{in } C+ \text{ will be} = +\tfrac{1}{2}\cdot\frac{x''}{2}$$

Similarly that

$$\text{in } C- \text{ will be} = -\tfrac{1}{2}\cdot\frac{x''}{2}$$

$$C+ - C- = +\frac{x''}{2} = +0''\cdot40$$

from which $x = 0''\cdot8$

$= 1\cdot2$ micrometer divisions.

Considering the procedure and the capabilities of the instrument, with an examination of the results of measurements at various times, it is difficult to understand how an error of this size could exist, if due precautions have been taken in determining the value of the interval.

The measurements from which the mean value is deduced exhibit, as a rule, a probable error of about $\pm0\cdot05$ division, and through changes of temperature affect the value of the interval, since we are measuring in terms of a revolution of a steel screw, a certain length of the brass travelling plate of the micrometer, still the errors due to such cause cannot be appreciable, if the measurements are made in temperatures, differing little from those obtaining during the latitude observations, as the effect of a change of temperature of 10° F is approximately 0·04 micrometer division.

In the difference between C+ and C—, we might, in the extreme case, attribute to these sources of error, $0''\cdot04$, but certainly no more.

TABLE VII.

STATION	By using micrometer value =69·127		By using micrometer value =69·110		Effect of error in adopted value
	Latitude	Probable Error	Latitude	Probable Error	
1	2	3	4	5	6
	° ′ ″	″	° ′ ″	″	″
Madhupur	23 56 42·82	± 0·040	23 56 42·82	± 0·029	± 0·168
Charaldánga	24 52 453·6	± 0·051	24 52 45·36	± 0·041	± 0·198
Chanduria	25 44 31·93	± 0·058	25 44 31·93	± 0·051	± 0·162
Lohágara	26 2 13·96	± 0·055	26 2 14·10	± 0·043	± 0·221
Jalpaiguri	26 31 9·16	± 0·056	26 31 9·16	± 0·043	± 0·179
Siliguri	26 41 18·10	± 0·080	26 41 18·03	± 0·065	± 0·192
Kurseong	26 51 15·05	± 0·060	26 51 14·96	± 0·054	± 0·188
Senchal	26 58 32·98	± 0·091	26 58 32·90	± 0·053	± 0·217
				Mean	± 0·191

12. The mean error shown in Table V is

Effect of error in adopted micrometer constant.

$$+0''\cdot017 \text{ per revolution,}$$

and the correct value for the micrometer constant would appear to be

$$69''\cdot127 - 0''\cdot017 = 69''\cdot110\,.$$

The use of this corrected value in the computations would give the results shown in Table VII.

At Lohágara, although all possible pairs of stars from Newcomb's Catalogue between R.A. $0^{h}\text{-}33^{m}$ and R.A. $13^{h}\text{-}33^{m}$ were observed, it was found that a balance between positive and negative micrometer corrections could not be effected, without rejecting more than a third of the observations.

In computing the final value for the latitude, this balance has been effected. But for purposes of analysis and the investigation into the effect of the use of a different micrometer constant, the relative results from the two levels, the difference of results given by the Greenwich and Newcomb Catalogues, etc., where the object is merely to make a comparison, all the observations have been considered. Consequently in the case of Lohágara, the final value for the latitude given in Table I is not comparable with those appearing in later Tables.

Assuming that the elimination of errors due to the micrometer value used, leaving only errors due to other causes, has reduced the probable errors from the values of column 3 to those of column 5, we can calculate the probable effect of the former class of error on the result from single pair of stars. These results are given in column 6, the average value being $\pm 0''{\cdot}191$.

This means that had these errors, instead of being systematic, been purely accidental, their probable value in the result from one pair of stars observed twice would have been $\pm 0''{\cdot}191$.

This is twice the size of the probable error of $\frac{1}{2}(\Delta_n + \Delta_s)$.

Had these errors been accidental and unconnected with the stars' place, it is evident that increasing the number of stars observed beyond a certain, not very large, limit would have small effect in reducing the probable error of the final result. This is all the more certain as the errors are systematic and not accidental.

Values of the Level Scale and results given by each Level separately.

13. The values of divisions of the level scales were determined by means of the Bubble Tester.

The two levels used were

Holmes No. 6	value of one division	= 0·89339.
Holmes No. 9		= 0·87611.

In the observations, care was taken to keep the corrections for dislevelment as small as possible, to minimize the effects of an error in the mean value adopted for the scale, and at the same time endeavours were made to balance the sums of positive and negative level corrections. But since in the computing, later on, it may be found necessary to reject certain observations, either on account of gross errors or to effect a balance of positive and negative micrometer corrections, it is not always possible, in the field, to form an exact balance of level corrections. Still it is always easy by careful attention during observations, to ensure that the residual dislevelment shall be small.

Table VIII shews the results given by the two levels used separately and conjointly.

TABLE VIII.

STATION	LEVELS USED CONJOINTLY		LEVELS USED SEPARATELY				No. 6—No. 9
			By No. 6 Level		By No. 9 Level		
	Latitude	Probable Error	Seconds of Latitude	Probable Error	Seconds of Latitude	Probable Error	
	° ′ ″	″	″	″	″	″	″
Madhupur	23 56 42·82	±0·040	42·84	±0·043	42·81	±0·039	+0·03
Charaldánga	24 52 45·36	±0·051	45·37	±0·052	45·38	±0·052	−0·01
Chanduria	25 44 31·93	±0·058	31·92	±0·058	31·93	±0·059	−0·01
Lohágara	26 2 13·96	±0·055	13·94	±0·054	13·98	±0·057	−0·04
Jalpaiguri	26 31 9·16	±0·056	9·16	±0·057	9·14	±0·056	+0·02
Siliguri	26 41 18·10	±0·080	18·15	±0·079	18·06	±0·085	+0·09
Kurseong	26 51 15·05	±0·060	15·09	±0·060	15·01	±0·062	+0·08
Senchal	26 58 32·98	±0·091	32·99	±0·093	32·97	±0·092	+0·02

From this it is not clear that the addition of a second level achieves any great improvement of result, when both tubes are good and the dislevelment corrections are kept small.

14. In Table IX are given particulars regarding the level corrections.

TABLE IX.

STATION	No. of stars observed	No. of observations	Residual Level correction in final Latitude	Probable Error of correction for one Level	E. W.—W. E. in Latitude
1	2	3	4	5	6
			"	"	"
Madhupur	80	89	−0·14	±0·071	−0·01
Charaldánga	90	96	−0·11	......	+0·02
Chanduria	75	72	−0·12	±0·040	+0·15
Lohágara	58	64	−0·04	±0·073	+0·02
Jalpaiguri	40	98	−0·02	±0·035	−0·12
Siliguri	33	37	−0·05	±0·069	+0·06
Kurseong	35	61	+0·14	±0·059	+0·05
Senchal	19	18	+0·11	±0·049	−0·14
Tonglu	21	17	......	......	−0·30
Phallut	23	14	......	......	−0·01
			Mean . .	" ±0·06	

As has been already stated, at Lohágara, the observations on 30 stars had to be rejected to effect a balance of positive and negative micrometer corrections. The total number of observations was 95 on 88 stars.

The fifth column gives a value for the probable error of the correction from a single level. This, however, is only an approximation, as it depends on the assumption, that the mean dislevelment from both levels is without error.

In September 1902, observations were taken on the Bubble Tester to determine independently, the probable error of a small correction from each level, the same part of the tube being considered, that was used in the latitude observations.

The results of the investigation were—

For No. 6 Level probable error of correction to a latitude result of half a second of arc . . = ±0"·13

For No. 9 Level " " . . = ±0·07

Probable error of correction from one level, *vide* Table IX = ±0·06

The relative sizes of the two probable errors show that the addition of the second level cannot be expected to materially improve the probable error of the final result.

This is borne out by the comparative values in Table VIII.

H. McC. COWIE, LIEUT., R.E.

III

THE MAGNETIC SURVEY OF INDIA.

Extract from the Narrative Report of Captain H. A. D. Fraser, R.E., in charge No. 26 Party (Magnetic), Season 1901-02.

2. During the year under report field work was commenced, the self recording instruments at Dehra Dun and Kodaikanal were erected and tested, and a good many special observations were taken. These various matters will be dealt with separately.

General Remarks.

3. Before alluding to the work of each field detachment it will be well to describe briefly the procedure laid down for observations in the field and to refer to the magnetic forms in use.

Procedure in the Field.

At each station occupied, the rule is that all three magnetic elements are to be observed, *viz.*, Dip, Declination and Horizontal Force.

4. These are invariably taken in the meridian with two needles, and the work is arranged symmetrically so that the mean result from both needles refers to a mean time that is common to both (*vide* foot-note to Form No. 4). In each position of the instrument a second reading is taken after raising and lowering the needle by the lifter; if the two readings agree within 2′ of arc the mean is accepted, but if not, one or more extra readings are taken according to circumstances.

Dip observations.

Calling d the average difference found between the results from the two needles in use, then individual values for this difference must fall within the limits $d \pm 2'$, and if at any station these limits are exceeded the observation is repeated with one or both needles.

All the field Dip circles were made by Dover and are of the ordinary Kew pattern except that they are provided with folding sights and with a simple arrangement for reversing the face of the needle without touching it by hand or opening the box.

The sights are fitted to facilitate the operation of setting the needle in the meridian. They are carefully adjusted at Dehra Dún before taking the field and thereafter their adjustment is tested once a month. Owing to the framework of the box of the instrument being of brass instead of wood, it is found that the adjustment of the sights once made seldom requires alteration. The sights are in adjustment when the vertical plane containing the front and back sights is parallel to a vertical plane containing the needle resting freely on the agate planes.

To make the adjustment the setting of the azimuth circle is first found in the usual manner by observing one or more of the needles when in the vertical position. The instrument is then directed by means of the sights on to some convenient mark whose position with regard to the magnetic meridian has been determined by the magnetometer, and the mean of two or more independent intersections is found. If the sights are in adjustment (as above defined) the difference of these azimuthal positions gives the angle between the mark and the magnetic meridian which is known. But if not, one of the sights is shifted laterally till the above condition is satisfied within from 2 to 5 minutes of arc. The sight is then screwed down and the adjustment is complete.

(*a*) Ordinarily speaking in the field, the Dip is observed before the Declination. In this case the sights are used as follows.—First one pair of readings of the two ends of the needle when vertical is made and entered in the left of the form and the mean of these is used as an approximate "setting of the azimuth circle" for the remaining operations, but before observing the Dip the Referring Mark (R.M.) is intersected with the sights and the readings recorded.

Subsequently when the observations are reduced in the recess season the last two lines on the left page of the form {marked (*b*) and (*c*)} are filled in as explained in the foot-notes and the correct setting of the azimuth circle is thus found. The difference between this and the setting actually used is the error in setting which may be denoted by α

Then if I be the meridional dip
and I_α the dip observed
we have $\cot I_\alpha = \cot I \cos\alpha$
from which I is easily found.

It is plain that below a certain value for α the correction becomes negligible and to find this value we may assume that under the most favourable conditions it is only possible to observe the Dip correctly to $0'{\cdot}1$ so that α may therefore be neglected when the correction due to $\cos\alpha$ does not exceed half this amount, *viz.*, $3''$.

Then giving I its largest probable value in India, *viz.*, 50°, I_α is by supposition $50^\circ\ 0'\ 3''$, whence α is found from the above equation to be about $26'\ 25''$.

In reducing last season's work, out of 113 stations at which this method was used, there were only three cases in which corrections had to be applied to the observed Dip, so that the above system may be considered a satisfactory time-saving method and its use will be continued.

(*b*) When the Declination has been observed before the Dip, the correct azimuthal setting is found directly from the recorded mean intersection of the R. M. and no observations of the needle for this purpose are then required. This affords a quick and accurate method of setting the instrument in low magnetic latitudes where it is exceedingly tedious and sometimes almost impossible to intersect the needle at all when in the vertical position.

Thus the sights are used to save time in either of two ways; (1) by affording a means of correcting an approximate setting, (2) by giving at once an accurate setting if the Declination has already been observed. The first is the method commonly used in the North of India, the second having special merits where the inclination is small.

Declination observation.

5. As the Cooke's magnetometers in use in the field are not adapted for astronomical observations, the procedure adopted is to determine the angle between the magnetic meridian and a referring mark or R. M. and to find the astronomical azimuth of the line from the centre of the instrument to the R. M. by star observations with a 6-inch vernier theodolite. Instead of observing the azimuth from the station to the R. M. it has been found more convenient in practice to determine the reverse azimuth from the R. M. to the station. The theodolite stand is therefore erected in any convenient position generally from 200 to 350 yards away from the station and a round peg or similar object is then placed vertically in the central aperture in the tripod head and used as the R.M. from the magnetometer. When the azimuth is being found this peg is removed, the theodolite erected in its place and the magnetometer itself is used as the R. M. from the theodolite.

The azimuth work is always done at night either by observations to Polaris, the time being known or by observing a pair of East and West stars in the cross wires: observations to the sun are permitted only in dull weather when the stars are obscured. Consequently a luminous R. M. is required and the small lamp provided with the magnetometers when used in conjunction with the iris diaphragm answers the purpose admirably. As the iris diaphragm is not vertically over the centre of the instrument, it is however necessary to set and clamp the Horizontal circle so that the line connecting the aperture of the diaphragm with the theodolite shall pass vertically over this point. This plan was found very convenient as the lamp used to illuminate the diaphragm is protected by the observatory tent and burns steadily in all weather, whilst the observer is able to use his theodolite at a height more convenient than that afforded by the universal tripod of the magnetometer.

A description of the Survey Pattern Magnetometer made by Messrs. T. Cooke and Sons has already appeared in *Terrestrial Magnetism* for July 1901 and need not be here repeated. The method of eliminating the torsion angle and the use of phosphor-bronze ribbon in place of silk is there alluded to and as

in all other essential respects the method of taking the Declination observation is similar to that practised at Kew, no further description is necessary.

The adoption of phosphor-bronze as a means of suspension was due to the suggestion of Professor W. Watson, F.R.S., and has proved eminently satisfactory. With care it rarely breaks, whilst the correction on account of torsion is generally *nil* and never exceeds a few seconds of arc. The saving in time is also considerable.

The specimen Form No. 1 explains itself and the large Roman numerals show the order in which the various operations are performed.

All readings both to the R. M. and to the magnet are taken in duplicate and by properly using the scale engraved on the telescopic diaphragm different parts of the arc are brought into use each time so that each reading is quite independent and unbiased, whilst any error in the assumed scale value is made to cancel out. In the event of two consecutive readings differing by 20" or more, one or more extra intersections are taken. Also the value found for the "Magnetic collimation angle" (*vide* Form No. 1) must lie within 20" of its previous mean value, failing which a second complete observation must be made.

Horizontal Force observations.

6. At each station one set of deflections is taken immediately preceded and followed by a set of vibrations.

Observation of mH.

(*a*) A specimen Form No. 2 is appended showing the method of booking a vibration observation. It will be seen that every 9th vibration is observed and that the time taken for a complete set is from 12 to 13 minutes. As each field detachment is provided with a recorder to relieve the observer to some extent of clerical and accounts work, and to assist in the computations, the following procedure has been adopted. The approximate time of 18 vibrations having been found, the observer produces a vibration of about 45′ on each side of the centre, care being taken that there is no visible cross oscillation of the magnet as a whole. With the chronometer on the ground in front of him he notes the time of the first passage of the cross lines on the magnet past the central division of the eye-piece scale. The recorder books this and, adding on the time found for 9 vibrations, gives out the time of passage of the 9th vibration to the nearest half second. The observer then notes the time of passage to the nearest tenth of a second and the same process is repeated till the whole set has been completed. In this way the observer is able to concentrate the whole of his attention on the actual observation of the times and, not having the figures before him, is to a very large extent freed from bias.

After the set is completed the means are at once taken out and the results scrutinized. Should the highest and lowest times for 162 vibrations differ by 0·5 second or more, or should the two mean results differ by 0·05 second or more, the result is considered unsatisfactory and a fresh observation is at once made. When the whole set of force observations has been completed a further test must be complied with as will be seen below.

If the torsion coefficient has been determined already in the course of the Declination experiment no further observation for torsion is made.

Before commencing this observation, the point on the vertical scale, which is crossed by the intersection of the cross lines on the magnet when the latter is swinging freely, is recorded at the head of the form: this is done merely to check the balance of the magnet which varies remarkably little from place to place.

The occurrence of an abnormal value would draw the observer's attention to the fact that there was something amiss, and cause him to set things right before proceeding. As a matter of fact, however, abnormal values have not been noted in practice.

Observation of $\frac{m}{H}$.

(*b*) The specimen Form No. 3 attached shows that the ordinary Kew method of making the Deflection experiment has been departed from in several important particulars, *viz.*, the distances selected, the use of 3 distances in place of two and the arrangement of the observations.

The inclusion of the nearest distance, *viz.*, 22·5 cms., is in accordance with the practice at the Colaba Observatory where the two distances selected are, in the case of the standard instrument, 0·8 and 1·0 foot or 24·4 and 30·5 cms

approximately. The object is merely to increase the size of the deflection angles measured, for the errors of instersection and of reading the verniers being the same in all positions, the percentage of error due to these causes varies inversely with the magnitude of the angle measured, and owing to the large value of H in India, the angle at 40 cms. is generally less than 5 degrees with magnets of the size used.

The object of observing at 3 distances, (that is of including the distance 40 cms. in the observation) is to obtain data for evaluating the second term in the expression for the distribution coefficient which is of the form $\left(1 + \frac{P}{r^2} + \frac{Q}{r^4} + \ldots\ldots\right)$. This question is dealt with in a separate paper now in course of preparation and will not be here discussed. It is only necessary to mention that the results of the observations at the 40 cm. distance are not at present directly used in the reductions, in which the usual practice is followed of ignoring all terms involving the fourth or greater powers of "r" in the expression above given. It is intended eventually to publish a table of corrections showing the results of including the "Q" term in the reductions, but there would not have been sufficient justification for undertaking this investigation were it not for the extreme facility of taking Deflections with the Cooke Magnetometers and for the fact that owing to the arrangement of the order of observing, the extra time taken, short as it is, does not tend to reduce the weight of the result.

Following the practice at Kew the arrangement of observations at 3 distances would be as follows :—

Magnet East.

Distance cms.	North end
22·5	E
30	W
40	E
40	W
30	E
22·5	W

Magnet West.

Distance cms.	North end
22·5	W
30	E
40	W
40	E
30	W
22·5	E

In Form No. 3 the observations at 22·5 cms. are grouped together in the centre; above and below these are the observations at 30 cms., whilst those at 40 cms. occupy the beginning and end of the form. It has already been pointed out that the percentage error of observation varies inversely as the size of the Deflection angle, and the value of $\frac{m}{H}$ derived from the nearest distance must therefore have a greater weight than the other values. The present arrangement of the observation has been designed with the object of still further increasing the weight of $\frac{m}{H}$ from the near distance, for the shorter the time occupied by any set of observations the less is the chance of error arising owing to irregularity in the values of the force during the time of observation.

The observations at the near distance having thus been strengthened as far as possible, it follows that the value of $\frac{m}{H}$ derived from this distance should be used in the reduction of m and H, in preference to the mean value of $\frac{m}{H}$ derived from two or three of the distances chosen. This explains the foot-note in the right bottom corner of the form, but it may be remarked that it is only possible to combine the values of $\frac{m}{H}$ from the 22·5 and 40 cm. distances when the second term in the distribution coefficient is *nil*. For if this is not the case the values of P (derived in the usual manner) differ for the first and second pairs of distances, so that even when the error of observation is *nil*, the values of log. $\frac{m}{H}$ from 22·5 and 40 cms. will not agree. As long therefore as the second term in the distribution coefficient is neglected the Deflections taken at 40 cms. cannot

be directly used for finding the value of log. $\frac{m}{H}$ by the ordinary method of reduction.

It is true that to attain a given accuracy in $\frac{m}{H}$ the true value of the shortest distance requires to be known more accurately than either of the others; but as in these instruments the error in setting the deflecting magnet is practically *nil*, the absolute error due to r which is introduced into the result is in the nature of a constant and can therefore be taken into account under the head of instrumental differences.

The arrangement adopted for taking Deflections is open to the objection that individual values of P have less weight than they would have in the Kew arrangement, except when the temperature and the intensity vary uniformly or are constant throughout the observation, and such conditions are of course exceptional.

In making the final reduction a mean value of P derived from the whole season's work is however used, and there is no reason to suppose that there will be any accumulation of error in any given direction in the course of a long series of observations taken in different places and at different hours of the day. So that the mean value of P should in the long run be the same whichever method of arrangement is used, and if this is granted, the plan adopted of using only that value of log. $\frac{m}{H}$ derived from the nearest distance for finding m and H appears to have advantages tending towards increased accuracy.

The method of computing P used in the form is taken from the formula given at page 508 in "*Nature*" of September 29th, 1887. The formula is—

$$P = \frac{l-l_1}{\mu} \times \frac{r_1^2 r^2}{r_1^2 - r^2} - \left\{\frac{l-l_1}{\mu}\right\}^2 \times \frac{r_1^2 r^2 (r_1^2 + r^2)}{2(r_1^2 - r^2)^2}$$

where $l = \log. \frac{m_1}{H_1}$ derived from the distance

$l_1 = \log. \frac{m_1}{H_1}$ " " "

and $\mu = 0{\cdot}43429$.

The values of r are taken as 22·5, 30 and 40 cms. exactly, instead of using their true values which do not differ largely from the round numbers above given.

Since Form No. 3 was drawn up tables have been computed from the above formula, in which using $l - l_1$ as the argument the resulting value of P is found without further computation, and as these tables are likely to be of general use they are published at the end of this report.

(*c*) Before leaving a station the observer computes out the values of P and m from the vibration and Deflection experiments using, in the latter case, the best mean value of P available.

The observations must pass the following tests.—

(1) The value of P from 22·5 and 30 cms. must lie within 5 per cent. of its previous mean value.

(2) The value of P from 30 and 40 cms. must lie within 10 per cent. of its previous mean value.

(3) The values of m must lie within 0·002 per cent. of the previous mean value.

These tests are derived from working experience in the field and with Cooke's instruments furnish a useful guide to the reliability of the results.

The first two show that the Deflection experiment may be relied on and that the value of log $\frac{m}{H}$ is not far from the truth. If therefore the values found for m lie beyond the limits given the vibrations must be repeated.

General remarks on the procedure in the field.

7. Before dealing with the results obtained in the field certain other points involved in the usual routine will be referred to.

The stations of observations are spaced at intervals of about 40 miles apart when working along railway lines; when the route is covered by marching the rule is that observations are taken after two full days' travelling, so that the interval between stations then varies from 25 to 40 miles according to the nature of the country.

Each station is occupied as a rule for two nights and one whole day, so as to give the observer and his detachment an interval of comparative rest.

Each party is furnished with a complete set of maps generally on the scale of 4 miles = 1 inch; the position of each station is marked on these maps in the field and its latitude and longitude obtained. All longitudes are eventually, reduced to that of Greenwich taking that of Madras at its latest value, *viz.*, 5h. 20m. 59·11s. East.

In cases of doubt as to the exact position of a station on the map, an observation for latitude is made either to Polaris or by circum-meridian altitudes to a north or south star.

Generally speaking observations for time and rate are made to stars at each station, of which only a sufficient number are worked out in the field to give the observer working values for the error and rate of his chronometer.

The Field work.

8. At the commencement of the season under report, the only base station in working order was that at Colaba (Bombay), but the installation of the magnetographs at Dehra Dún was to be undertaken as soon as possible. Consequently it was decided to confine field operations to the country west of a line joining Bombay and Dehra Dún and to start the three field parties available in the southern portion of this area.

Mr. Hunter's detachment.

9. Mr. Hunter's detachment which was the first to start, commenced work early in November at Deesa. He made a long march round the Rann of Cutch returning to his starting point about the 9th of February and afterwards made two marches across the Rajputana Desert, 36 stations being observed at in all.

R. P. Ray's detachment.

10. This detachment commenced work about the 20th November, the observer having been kept back for a few weeks' extra training and preliminary field work in the neighbourhood of Dehra Dún.

The detachment began operations at Karachi and thence traversed the greater part of the broad gauge system of railways administered by the North-Western Railway Company, observing at 65 stations.

K. K. Dutta's detachment.

11. The third field detachment in charge of observer K. K. Dutta left Dehra Dún about the 24th November, having also been detained rather longer than anticipated in Dehra Dún for training. Work was commenced near Bombay and in the course of the season observations were completed at 62 stations, chiefly on the railway lines controlled by the Bombay, Baroda and Central India Company.

The reduction of the field work.

12. With regard to the reduction of the observations in recess, a few points only deserve mention.

The method of finding the mean value of P to be adopted for the season's work was as follows :—

A general mean value was found from all the individual values obtained. Then in the case of P from 22·5 and 30 cms., all individual values falling outside 5% limits from this mean were rejected. The values left in gave a new mean value and the above process was repeated till no further material change in the mean value of P resulted.

The value of P from 30 and 40 cms. was found in a similar manner except that 10% limits were used.

This purely empirical method was adopted as the result of Captain Fraser's experience with No. 1 instrument, and, as the values of P in the different instruments do not differ very largely, it was applied generally.

Then in computing the values of m and H, ordinarily log. $\frac{m}{H}$ derived from the 22·5 cm. distance was used, but where the resulting value of m differed largely from its mean value, log $\frac{m}{H}$ from 30 cms. was tried instead. If this also gave a wide value for m, the deflection observation was rejected altogether and values of H were found from log $m\ H$ by giving m its mean value.

Throughout the season all chronometers were kept within 1 minute of Madras time, which will be used subsequently for all parts of India when applying the corrections for magnetic perturbations. Later on it will be seen that the Dehra Dún magnetograph was not avaliable till the 1st March and the

correction of all field observations before that date will therefore rest only on the records given by the Colaba Observatory.

13. It had been intended to compare each field instrument with the Survey standards before sending it out for work, but this part of the programme had to be abandoned because the Dehra Observatory was not in working order, and all spare time had to be devoted to training the observers. In future comparisons will be made at the beginning and close of each season to determine the instrumental corrections for reducing all results to the Survey standard.

Instrumental corrections to the Survey Standards.

15. Another important piece of work was accomplished before the end of June. This was the determination of the values of Log. $\pi^2 K$ for each of the instruments in stock. In the first instance Magnet No. 1A was tried with 5 different inertia bars belonging to instruments Nos. 1, 2, 3, 4 and 6 respectively.

Determination of the moments of inertia of the Survey magnets.

The results are exhibited in the following table:—

Values of $\pi^2 K$ for Magnet No. 1A using different inertia bars.

Bar No. 1.	Bar No. 2.	Bar No. 3.	Bar No 4.	Bar No. 6.	Remarks.
3·370415	3·370573	3·370385	3·370252	3·370557	All observations taken by Chronograph.
244	399	285	376	878	
337	521	398	147	787	
191	464	439	088	792	
300	...	...	544	908	
508	...	...	170	866	
258	...	...	023	...	
3·370322	3·370489	3·370377	3·370229	3·370813	Mean values.

General mean=3·370446.

Now assuming uniform density in the bars, then if their weights and dimensions are correctly known the mean results of these experiments should have been identical. Although the variations from the mean are larger than might be expected, there is little doubt that the mean values indicate the existence of real differences and as all the bars were measured at Kew with similar precautions, one is forced to conclude that the densities of the bars were not uniform.

In the absence of evidence to the contrary there is no reason to prefer the result obtained from any one bar to the others, and it was therefore decided to adopt as the standard inertia bar of the Survey that one which gave a result most nearly approaching the mean from the whole series. In this way Bar No. 2 was selected as the standard, and was then used with all six Cooke instruments to determine the moments of inertia of their magnets.

The whole of these observations were made with the aid of a chronograph connected with the standard sidereal clock. The method adopted was to start with the magnet alone suspended and tick off 20 consecutive passages; then after an interval of 5 minutes, 20 more passages were taken. The total number of vibrations was easily found from the record, this being always an even number as the first passages were always taken in the same direction. The bar, which was kept in the magnet box from the first, was then put in position and the system made to balance within 1 scale division or say 80″ of its first position. Two sets of vibrations were similarly taken *with bar*, then the bar was removed and two sets taken without bar and so on. Observations for finding the torsion coefficient were frequently taken and no set of vibrations was commenced till the readings of the thermometer showed that the disturbance of the temperature conditions which is inevitable in making the various changes had practically disappeared. Various other precautions were taken in matters of detail which need not be here described. The first four sets were then combined to give one result for $\pi^2 K$, then the last two of this first group were combined with the next two and so on, each result being

thus semi-independent of its neighbour. Thus a series of 12 sets of vibrations taken without a break will furnish five results of which the 1st, 3rd and 5th will be quite independent. An example of the method of reduction is given on Form No. 5 at the end of this report.

Any group of vibrations taken during a period of disturbance of the H. F. was rejected.

Unfortunately inertia Bar No. 2 is too large for use with magnets Nos. 16, 17 and 20 belonging to the old Kew pattern instruments which have been altered for use at the base stations. However Bar No. 17 was found to fit the other two instruments and No. 1 Cooke as well, so the moment of inertia of magnet No. 1A was re-determined using Bar No. 17. The difference in the results obtained thus and with the standard Bar No. 2 was considered to be a constant and applied to the values of $\pi^2 K$ found with Bar No. 17 in order to reduce them to the Survey standard.

The following table exhibits the results obtained :—

Values of Log. $\pi^2 K$ for various magnets using the standard Bar No. 2.

Magnet Number.					Remarks.
1 A	3 A	4 A	5 A	6 A	
3·370573	3·387279	3·379431	3·378852	3·398893	
399	390	283	8938	903	
521	263	396	8990	863	
464	242	334	8922	932	
324	399	253	8843	830	
512	443	229	9033	906	
389	444	481	9014	911	
578	416	410	8964	801	
409	329	451	...	773	
488	218	362	...	884	
508	231	320	...	877	
363	...	382	...	866	
377	...	361	...	823	
478	...	...	...	883	
546	...	...	...	...	
3·370462	3·387332	4·379361	3·378945	3·398868	Mean values.

Values of Log. $\pi^2 K$ for various magnets using Bar No. 17.

Magnet Number.			Remarks.
1 A	16	17	
3·370051	3·386952	3·415341	To find the values of log. $\pi^2 K$ referred to the standard No. 2 the quantity 0·000239 is to be added to the mean values found for magnets Nos. 16 and 17, which then become
140	6711	565	Log. $\pi^2 K$ for magnet 16=3·387166.
091	6731	599	„ 17=3·415809.
348	6939	666	
307	6973	588	
265	7158	307	
253	6992	339	
149	6902	623	
248	6808	615	
270	6830	699	
170	6869	662	
286	6987	469	
326	7204	574	
...	...	735	
...	...	773	
3·370223	3·386927	3·415570	Mean values.

It may here be mentioned that the experiments made with magnet 2 A., gave most discordant results, the cause of which is now under investigation.

It is intended to take a short series of observations once a year with each instrument as a check on the constancy of the values above found.

Repeat stations.

16. Five repeat stations situated in the area under survey were observed at by the officer in charge during March and April, after the Dehra Dún base station had.

been fairly started. These were situated at Udaipur, Karachi, Quetta, Baháwalpur and Ráwalpindi. At each of these places complete sets of observations were taken at each of three points about 1 or 1½ miles apart and symmetrically placed. When finally reduced the mean magnetic results will be referred to a point representing the mean geographical position of these three points. At each point a mark pillar was erected to locate the spot for future reference and the observations were extended over a period of from three to five days.

It is intended to repeat the observations at these and all other repeat stations subsequently selected once every year during the progress of the survey. Their average distance apart will be about 400 miles.

The Dehra Dún magnetographs.

17. As soon as the last of the field detachments left Dehra early in December the officer in charge erected the Horizontal Force and Declination Magnetographs in the underground room which was by this time relatively dry, though the walls were still coated with damp.

The second set of Watson's magnetographs was then erected on temporary wooden trestles in a room in the 12-inch photo-helio observatory.

A sufficient description of the magnetographs designed by Professor Watson has appeared in *Terrestrial Magnetism* for December, 1901, to which reference should be made.

Certain points which came under notice in erecting the instruments at Dehra Dún will now be dealt with.

The Horizontal Force Magnetograph.

(*a*) To commence with the Horizontal Force instrument, it is necessary —

(1) that the suspended magnet shall be constrained by the torsion in the quartz suspension to lie very nearly true E. and W. (magnetic);

(2) that the magnet used in finding the scale value by means of deflections shall be placed very nearly true magnetic south from the centre of the suspended magnet and approximately in the same horizontal plane;

(3) that the true distance between the centres of these two magnets be known with considerable accuracy.

With regard to (1) the following method was adopted :—

First using a silk suspension, freed from torsion, the body of the instrument was turned till the magnet appeared to be exactly parallel to the sides of the copper box in which it is suspended. As this cannot be done with any great refinement, the operation was repeated several times and a mean reading of the divided horizontal are corresponding to this position was thus obtained.

Then after substituting the quartz for the silk fibre, the whole instrument was turned through 90° clockwise and clamped in position. By revolving the divided torsion head in the same direction the magnet was again brought into a position parallel to the sides of the copper box and the reading of the torsion head noted. The mean of several settings obtained independently gave the adopted value of the torsion head circle. Judging from the accordance of the different readings in the two parts of the operation it seems improbable that the error in the alignment of the magnet can have exceeded 0°·3.

The mirror was then adjusted laterally by the screws provided for this purpose till the spot of light was within a few scale divisions of the desired position on the drum, after which the slow motion arrangement was clamped in position on the torsion head and the final lateral adjustment effected by its means.

(2) Before erecting the magnetographs, an observation was made with a magnetometer placed centrally in the underground room for the purpose of laying out the position of the magnetic meridian on the north and south walls of the room. Having obtained this line it was easy to lay out a line parallel to it and passing through the centre of the suspended magnet and to mark its position on the metal box connecting the magnetograph with the recording mechanism. The bracket provided on this box for carrying the Deflecting magnet was then shifted laterally till the centre of the magnet lay in this line and the adjustment for horizontality was made approximately by means of an ordinary box level.

A second bracket was similarly fixed in position so as to provide a second Deflection distance as it was considered advisable in the case of the first installation to find by experiment whether the distribution term *P* could be safely neglected in the formula for finding the scale coefficient.

(3) The distances between the two magnets were measured by means of an ordinary beam compass to each corner of the copper box from the centres of the holes in the deflection brackets. Each measure was at once read off (in feet and decimals of a foot) from a 10-foot divided bar by Troughton and Simms. On repeating the measure the observers changed ends and if the two measures when read off the divided bar were not in close agreement a third measure was taken. The magnet having been adjusted to occupy the centre of the box as nearly as could be judged by eye, the mean of all the readings gave the distance required in feet which was then converted into metrical units.

The two distances so found are—

1st distance = 37·807 inches.
= 96·028 cms.
2nd " = 47·227 inches.
= 119·954 cms.

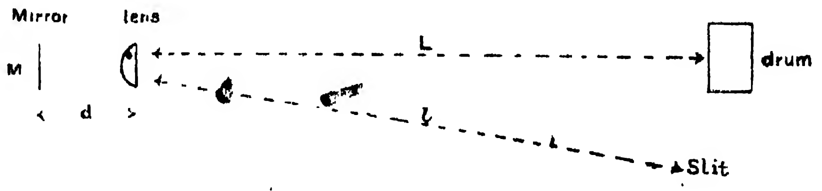
The Declination magnetograph.

(*b*) The suspension in this instrument is a fine phosphor-bronze ribbon: it was freed from torsion by suspending a small bar plummet of about the same weight as the magnet system, and turning the torsion head till the plummet assumed a central position with regard to the copper damping box, which had previously been aligned in the magnetic meridian.

After all adjustments had been made and a satisfactory record obtained for several days, the necessary measurements were taken for determining the scale value of the instrument.

Fig. 1 represents the optical arrangement of this instrument, except that the cylindrical lens in front of the drum has been omitted for the sake of clearness.

Fig 1



Let f = focal length of the lens.

Then the lens forms an image of the slit at a distance v, the image being on the same side of the lens as the slit, *i.e.*, virtual, where v is given by

$$-\frac{1}{f} = \frac{1}{v} - \frac{1}{l} \quad . \quad . \quad . \quad . \quad . \quad (i)$$

$$\therefore \frac{1}{v} = \frac{1}{l} - \frac{1}{f} = \frac{f-l}{fl}$$

The distance of the image from the mirror is $v + d$.

Hence the distance of the image formed by reflection in M from the lens is $v + 2d$. The image of this image formed by the second transmission through the lens is on the drum, *i.e.*, at a distance of L.

$$\text{Hence } \frac{1}{f} = \frac{1}{v+2d} + \frac{1}{L} \quad . \quad . \quad . \quad . \quad . \quad (ii)$$

$$\text{From } (i) \text{ and } (ii) \; -\frac{1}{v} + \frac{1}{l} = \frac{1}{v+2d} + \frac{1}{L}$$

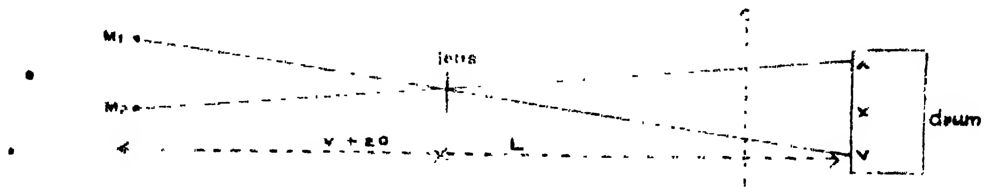
From which v may be found. However in the case of the magnetographs v is very great compared to $2d$.

$$\text{Hence } \frac{2}{v} = \frac{1}{l} - \frac{1}{L} = \frac{L-l}{Ll}$$

$$\text{or } v = \frac{2Ll}{L-l}.$$

Next suppose that the mirror rotates through a small angle α and let x be the movement of the spot of light on the drum. We may suppose the mirror removed and the system to be as shown in figure 2.

Fig 2



M_1 and M_2 are images formed in two positions of the mirror which is supposed to be removed.

Then since the reflected beam moves through double the angle of movement of the mirror and since M_1 and M_2 are at a distance of $v+d$ from the mirror, we have

$$M_1 M_2 = (v+d) 2\alpha \quad \text{where } \alpha \text{ is very small.}$$

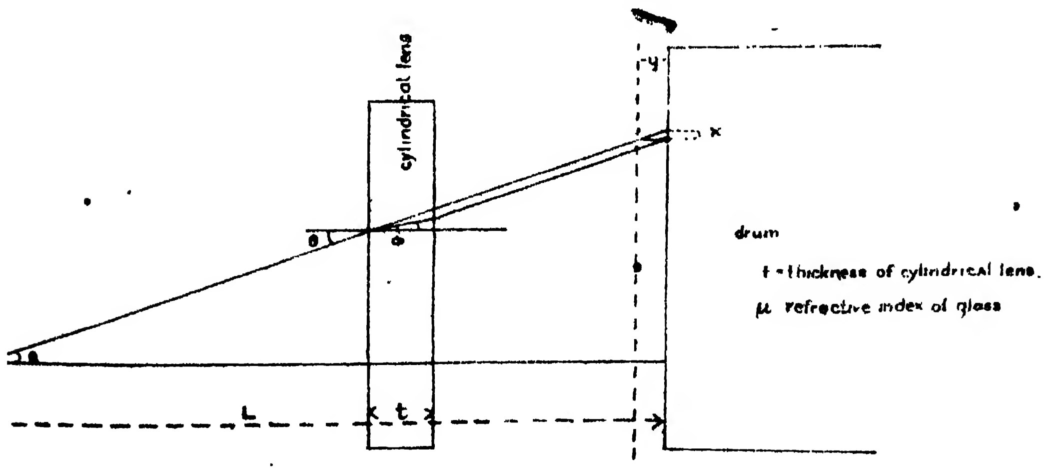
$$\text{But } \frac{x}{M_1 M_2} = \frac{L}{v+2d}$$

$$\therefore \frac{x}{(v+d)\,2\alpha} = \frac{L}{v+2d}$$

$$or\ \alpha = \frac{x}{2L} \cdot \frac{v+2d}{v+d} = \frac{x}{2L}\left\{1 + \frac{d}{v+d}\right\} \quad \ldots \quad (iii)$$

Next to consider the effect of the cylindrical lens situated at about C above.

Fig 3



Owing to refraction in the lens the deviation of the ray on the drum is not so great as if the lens were not present: this effect corresponds to placing the drum nearer the instrument at, say, a distance L-y. (Fig. 3).

We have to find y.

We have $x = t\,(\tan\theta - \tan\phi)$
or since both θ and ϕ are small

$$x = t\,(\theta - \phi)$$

$$\text{also } \mu = \frac{\sin\theta}{\sin\phi} = \frac{\theta}{\phi}$$

$$\therefore x = t\left(\theta - \frac{\theta}{\mu}\right) = t\,\theta\left(1 - \frac{1}{\mu}\right)$$

Now $\mu = 1 \cdot 5$, so that $x = t\,\theta\left(1 - \frac{1}{1 \cdot 5}\right) = \cdot 33\, t\,\theta$

$$\frac{x}{\tan\theta} = \frac{x}{\theta} = \cdot 33\, t$$

Hence equation (*iii*) ought to be written

$$\alpha = \frac{x}{2\,(L - \cdot 33\, t)}\left\{1 + \frac{d}{v + d}\right\} \quad . \quad . \quad . \quad . \quad . \quad (iv)$$

The above formula is due to Professor Watson; the values of the different quantities as measured for the Dehra Dún Declination magnetograph are as follows:—

Distance from slit to front of lens	$= l$	$= 60 \cdot 504$ inches
" " drum " "	$= L$	$= 67 \cdot 030$ "
" " back of mirror " "	$= d$	$= 0 \cdot 65$ "
Thickness of cylindrical lens	$= t$	$= 0 \cdot 13$ "

Then putting x equal to 1 division of the glass measuring scale, *i.e.*, $\frac{1}{25}$th inch, we obtain $\alpha = 61'' \cdot 62$.

The corresponding value for 1 m m of ordinate is $60'' \cdot 65$.

18. During the first week in January, 1902, a series of experiments were undertaken for finding the temperature co-efficient of the Horizontal Force magnetograph. The opportunity was taken for making similar experiments with the quartz fibres and magnets belonging to magnetographs Nos. 2 and 3, which were to be erected at Kodaikanal and at Barrackpore, respectively. This work occupied the officer in charge till the end of February and a full account of the procedure adopted and of the results obtained will shortly be published.

The temperature experiments.

19. On the 1st March, 1902, the regular records of the observatory were commenced and were carried on without serious interruption during the remainder of the year.

Precautions against damp.

(*a*) As the walls of the room again showed signs of damp shortly after the conclusion of the temperature experiments, a consignment of calcium chloride was obtained from Calcutta and was used in the drying box in place of quick lime, with very satisfactory results. Acting on a suggestion made by Professor Watson, the drying of the inner room was also greatly forwarded by using a number of common blankets. These were suspended in a dry state close to the walls of the room and at first taken out every day to be dried either in the sun or over charcoal fires according to circumstances.

The various measures adopted and now in use for drying the room are as follows:—

(1) A slight through draught is caused by burning a duplex lamp under the outtake, into which the burnt air from the two instrument lamps is also conducted; this induces a current of air and also keeps the temperature of the instrument room slightly higher than that of the surrounding passage.

(2) The fresh air to replace that expelled by the lamps enters through a vertical pipe over the lower part of the stair way; thence it is made to travel completely round the underground outer passage till it reaches the drying box. Here it passes over trays of calcium chloride to a brass pipe which enters the inner room close to the clock pillar and about one foot above the floor. By this time it is at the temperature of the outer passage and partially dried.

During the rainy season the external air is hotter than the underground room and nearly saturated with moisture, so that the effect of passing it round the underground passage is to cool it and cause it to deposit moisture on the walls, but it is still saturated when it reaches the drying box, the necessity for which is therefore apparent.

(3) Inside the room large earthen trays are kept on the floor and filled with quick lime, which is renewed from time to time as necessary.

(4) A number of common blankets suspended close to the walls also assist in drying the air of the room; these are removed and dried when necessary.

(c) The instruments themselves are covered with framed glass cases which are made nearly air tight and each contains a small tray of quick lime.

The combined effect of these various precautions has sufficed to remove all trace of moisture from the walls of the inner room which continued to get drier even during the rainy season.

(*b*) The measures adopted by the Public Works Department to prevent future inundations like the one that occurred during the rainy season of 1901, were commenced early in November of that year and completed during December. A 5-foot trench was dug all round the building to the level of the foundations; the foot of this trench was rendered into a concrete drain sloped from the north-east corner round to the south-east corner of the building where it discharged into a large earthenware pipe. This pipe was carried off about 150 feet in a southerly direction into a large open pit.

The whole trench was then filled with non-magnetic boulders up to the ground level, where its top surface was rendered into another shallow drain similar to that above described, except that the discharge from this surface drain was carried off in a south-east direction for about 100 yards along the natural slope of the ground.

The banked up earth over the underground room was stone faced with rubble masonry to a point well underneath the drip from the eaves of the thatched roof.

Thus the surface drain is designed to catch and conduct away all the rainfall on the site of the building and so prevent any percolation of moisture between the boulder trench and the underground walls; whilst any water that might reach the building owing to underground drainage during the rains is caught by the boulder trench and conducted into the open pit, which is large enough and deep enough to get rid of it by absorption and evaporation.

To still further guard against leakage, a drain pipe was connected to the lowest corner of the underground passage and led into a masonry well built a short distance away on the south side of the building. The end of this pipe was covered by a self-acting brass valve and the top of the well covered with a thatched roof.

The works above described withstood the test of the rainy season of 1902 satisfactorily and observation showed the amount of the underground drainage into the open pit to be exceedingly small and of only brief duration.

There was no leakage whatever into the all round passage or the masonry well connected therewith.

It is now confidently hoped that there will be no further trouble from damp or inundations.

20. The routine in the observatory is as follows :—

(1) Papers are changed on alternate days at 9h. 51m. local time, corresponding to 10 Madras time, and on intermediate days the lamps are shifted at the same hour.

(2) At this time also Deflections are taken every day by eye for the purpose of determining the scale value of the Horizontal Force instrument. Once a week photographic Deflections are recorded in place of those usually read by eye.

(The magnet used to produce the Deflections is the long or vibration magnet of the Dehra Dún magnetometer, whose moment is, therefore, accurately known.)

(3) At 10 every day the centigrade thermometer of the Horizontal Force instrument is read and readings are also made of a wet and dry bulb thermometer and of a Fahrenheit thermometer, the latter of which is kept under a glass case on a table placed along the north wall of the room.

(4) Readings of the centigrade thermometer are also taken every day at 13 and 16 hours.

(5) The calcium chloride in the drying box is changed as often as necessary (about every second day) and recalcined for further use.

(6) The blankets are removed, dried, and replaced on alternate days, or whenever necessary.

(7) The quicklime in the earthenware dishes on the floor and in the trays under the instrument covers is changed about once a week or whenever necessary.

Absolute observations are taken twice a week as follows:—

(1) Force observations consisting of a set of Deflections preceded and followed by a set of vibrations.
(2) A set of Declination observations including the evaluation of the torsion coefficient of the fibre in use.
(3) A set of Dip observations with two needles.

These observations are generally taken in the morning, but may be made at any time of the day.

The chronometer used is compared twice a week with the standard sidereal clock to determine its error and rate.

The bromide papers are developed and written up immediately after being removed from the drums.

The observer computes his absolute observations as soon as taken and makes a duplicate copy of the record, the originals and duplicates being separately made over once a week to the Head-Quarters Office.

During the first few months, a thermograph was kept in the underground room, but the changes of temperature were so small in amount and gradual in occurrence, that it was decided in the autumn to remove the instrument and trust to interpolation from the regular readings of the Centigrade thermometer for finding the temperature of the magnet at any desired time.

The reduction of the results and tabulation of the records will be undertaken as soon as the records for the year are complete.

The Survey Standards.

21. The absolute instruments allotted to the Dehra Dún Observatory are magnetometer No. 17, by Elliott Brothers and Barrow's Dip Circle No. 44. On the 1st of March only the latter of these was available as the old Elliott instruments had been sent for alteration to Messrs. Cooke and Sons and were not received in India till 29th April, 1902.

The Barrow circle repaired by Dover in 1900 was used throughout the year, and the two needles gave consistent results.

In place of magnetometer No. 17, it was decided to use No. 5 by Cooke, which was accordingly put into adjustment by the officer in charge, and used as the observatory instrument till the end of the year.

Moreover all observations were taken in the old south house till the 31st of December, 1902, inclusive, so that various corrections will have to be made to reduce the results to the survey standards and the new south house.

The Kodaikanal Magnetic Observatory.

22. Information having been received that the buildings were practically completed, the officer in charge left Mussooree early in July, 1902, to erect the instruments. There was a good deal of delay before work commenced owing to the difficulty of obtaining suitable stone slabs for the piers in the magnetometer room, but as soon as these were got into position the installation of the magnetographs was rapidly completed.

The observatory buildings are placed on the western slope of the hill about midway between the Solar Physics Observatory and the Director's house. They consist of an underground room 15 feet by 20 feet, protected by an all round passage, the design being similar in most respects to the building at Dehra. Above this room, and supported on its arched roof by means of teak pillars, is the absolute house, built entirely of wood except the floor and two instrument pillars which are of pressed tiles. These latter were tested and found to be very slightly magnetic when placed as close as possible to the box of the magnetometer, but a group of six of them produced no visible deflection when placed at a distance corresponding to the height of the top of the pillar, and it was therefore decided to use them for the floor and bodies of the pillars, the tops of which consist of marble slabs.

The height of the observatory is about 7,600 feet above sea-level and though admirably placed as regards its geographical position and for purposes of control, the site is not an ideal one for the base station of a magnetic survey owing to the fact that the rock on which it is built is distinctly magnetic. The same

rock occurs all round the observatory and there is no absolutely non-magnetic stone in the neighbourhood. Consequently the self-recording instruments in the lower room, some portion of which had to be blasted out of solid rock, are surrounded by a material which is to some extent magnetic, and it was chiefly in order to place the absolute instruments as far as possible from this source of disturbance that the absolute house was built above the lower room.

Being built in the side of a steep hill, the lower room was placed only partially underground from motives of economy and the exposed wall on the west side was banked up with earth having a minimum depth of 6 feet from the masonry. The outer passage drains naturally on to the road-way outside, and there is consequently no fear of any flood water finding its way into the inner room.

The erection of the instruments was effected without difficulty with the assistance of Mr. Michie Smith, the Director of the Solar Physics Observatory, and of Mr. Theodore, the magnetic observer.

The measures for finding the scale value of the Declination instrument and the Deflection distance were made in a similar manner to that before described, and the latter distance was found to be 39·454 inches or 100·20 cms.

In the formula for finding the scale coefficient of the Declination instrument the distances were:—

$$l = 61{\cdot}34 \text{ inches.}$$
$$L = 67{\cdot}02 \quad ,,$$
$$d = 0{\cdot}64 \quad ,,$$
$$t = 0{\cdot}13 \quad ,,$$

whence a was found to be 61″·55 for a scale division of $\frac{1}{25}$th inch.

A suitable pillar having been erected about 300 yards north of the building and a referring mark fixed therein, its azimuth was determined by observations to Polaris from the west pillar and found to be 186° 31′ 42″ from south. The angle between the two pillars was directly measured with a theodolite from the referring mark, its magnitude being 0° 28′ 14″. Hence the azimuth of the R. M. from the East pillar is 186° 3′ 14″

The Calcutta Observatory.

23. As mentioned in the last annual report, arrangements were initiated by the Meteorological Reporter to the Government of India for building the observatory at Madhupur, after it had been decided that the existing buildings at Alipore could not be used on acconnt of the electric tramways. It was, however, eventually decided to build an above-ground observatory at Barrackpore about 16 miles north of Calcutta. The designs were got out early in February, 1902, but for various reasons the work of construction could not be commenced till after the following rainy season, and consequently the erection of the instruments has had to be again postponed.

24. This building was completed about the end of 1901 and, early the following year, was inspected by Major Burrard, R.E., whilst on tour in Burma. However, it was decided to hold over the instruments obtained for Rangoon for use at Barrackpore which occupies a much more important position in the area to be surveyed than the former place. A new set of Watson's magnetographs was therefore ordered from the Cambridge Scientific Instrument Company, consisting of Declination and Horizontal Force instruments only; these are expected to arrive about the middle of 1903. At the same time the remaining old magnetometer No. 19, by Elliott, was sent to Messrs. Cooke and Sons to be altered and Barrow circle No. 43 will be allotted to the Rangoon Observatory when it has been fitted with sights by the Mathematical Instrument Office at Calcutta. The two Survey pattern magnets which had been obtained for use with the Alipore magnetometer, were returned by the Director of the Alipore Observatory when it was found that they would not be required for survey purposes, and will now be used in the instrument sent to England for repairs.

Everything will be ready for the Rangoon Observatory by the autumn of 1903, and the installation of the instruments will then be taken in hand, as soon as possible.

New Vertical Force Magnetograph.

25. When the scheme of the survey was first considered it was believed that Vertical Force magnetographs would be available at Bombay and Alipore, and Professor Rücker, F.R.S., in his letter to Government on the subject, based

his suggestions on the supposition that this would be the case. When Alipore was found wanting as a site for a base station it became necessary to order a set of self-recording Vertical Force instruments to supply the deficiency, and the Cambridge Company were therefore asked to make a set in accordance with Professor Watson's designs (*vide Terrestrial Magnetism* of December, 1901). This instrument is expected about June 1903 and will be erected in the Dehra Dún Observatory, which is better placed than Barrackpore for studying the variations in the Vertical Force, owing to its higher magnetic latitude.

It is therefore confidently expected that all five of the survey base stations will be in final working order early in 1904.

H. A. D. FRASER, CAPTAIN, R.E.

Survey of India.

Observations of ABSOLUTE DECLINATION with Magnetometer No. 1 by T. Cooke & Sons Date [illegible]

Station Bahawalpur N.G.S. { Lat. 29 22 53 / Long. 71 40 6 } Zero Reading (i.e. Centre of Scale) = 50 Temperature = [illegible]

Chronometer No. [illegible] Error + 34 - 12 Magnet No. 1a suspended. 1 of Scale = 1'.40

Readings of Referring Mark

	Reading of Verniers	Mean of Verniers	Scale Reading	Correction to Zero Reading	Corrected Circle Reading
	° ′ ″	° ′ ″	d	′ ″	° ′ ″
Before "Plummet swings at commencement."	333 30 20 / 30 40	333 30 30	49 0	+ 1 24	333 31 54
	333 33 20 / 33 25	333 33 23	51 0	− 1 24	333 31 59
After "Plummet swings at end."	333 34 40 / 34 50	333 34 45	52 0	− 2 49	333 31 56
	333 28 50 / 29	333 28 55	48 0	+ 2 49	333 31 44

Mean of Readings of R M = 333 31 53 (a)

Azimuth of R M (from S) = 222 15 58 (b)

‖ Meridian Reading of Circle = 110 15 55

Plummet swings at commencement (Position of zero torsion = 180°)

II

Setting of torsion head		Mean of (1) & (3)	Mean of (2) & (4), i.e. position of rest
96°	1st swing† 202.2 (1)		
	2nd „ 183.9 (2)	202.9 (4)	192.9 (5)
	3rd „ 203.6 (3)		

To eliminate torsion in the ribbon, alter the "setting of torsion head" by 180° − angle (5), adding for a + sign and subtracting for a − sign.

"Setting of torsion head for zero torsion" is now 95.1

III Observations of Declination

Magnet	Time	Reading of Verniers	Mean of Verniers	Scale Reading	Correction to Zero Reading	Corrected Circle Reading	‖ Meridian Reading of Circle	Declination ¶
	h m	° ′ ″	° ′ ″	d	′ ″	° ′ ″	° ′ ″	° ′ ″
Mark Below	[illegible]	114 3 30 / 3 50	114 3 40	49.0	+ 1 24	114 5 4	110 15 55	3 49 9
	[illegible]	114 6 30 / 6 40	114 6 35	51.0	− 1 24	114 5 11		3 49 16
Mark Above	[illegible]	114 5 20 / 5 20	114 5 28	48.0	+ 2 49	114 8 17		3 52 22
	[illegible]	114 [illegible] / [illegible]	114 8 35	52.0	− 2 49	114 8 26		3 52 31

Mean of times to nearest ½ minute	Mean with Mark Below (6)	= 3 49 13
	„ „ Above (7)	= 3 52 27
Error of Chron. „ „	E/W Declination (uncorrected)	= 3 50 50
	** Correction for Torsion	= — Nil —
[illegible] M T of Obsn. „	¶ East/West DECLINATION	= 3 50 50

[illegible] collimation angle = ½ [(6) − (7)] = − 1 − 37

IV Observations of Torsion

Setting of Torsion head for Zero torsion	Circle turned	Scale Reading	Means of pairs of 0°	Diff. of R.M. 0° and 180°	Sum of quantities in last col.
° 95		d	d	d	1.86
	0°	53.0			Value of 90° of torsion
	+ 180°	51.05	52.0	0.95	= Sum / 4
	0°	52.0			= 0.46
	− 180°	52.92	52.0	0.92	
	0°	52.0			

Correction for Torsion.

** Correction = − ½ [angle of torsion / 90° × Value of 90° of torsion]

= − $\frac{x}{2 \times 90}$

= −

Note.—When the torsion angle is E/W the sign is +/− for East Declination and −/+ for West Declination.

V Plummet swings at end.

	Mean of (1) & (3)	Mean of (2) & (4)	Angle of Torsion East or West ‡
1st swing [illegible] (1)			
[illegible] (2)	187.9 (4)	179.6 (5)	E/W 0.3
[illegible] (3)			

Observed by

Recorded by

Checked by

*† The correction is +/− according as the scale reading is greater/less than the zero reading.

† [illegible] the swings should not exceed 180°. [illegible] the torsion angle is in the direction of the angle (5) from 180° and is E/W according as the angle (5) lies between [illegible]

‖ [illegible] Reading of Circle [illegible] = $\frac{(a)-(b)}{360^\circ + (a) - (b)}$ [illegible]

[illegible] Meridian Reading of Circle"

Magnetic No 2

Survey of India.

Original
Duplicate

HORIZONTAL INTENSITY

Determination of TIME of VIBRATION and mH with Magnetometer No 1 by T. L. [illegible] Date 13 April 19[illegible]

Station Rawalpindi { Lat 33 34 [illegible] ; Long 73 [illegible] 2[illegible] }

Chronometer No 6543 { Error = + 29.36 sec ; Rate (s) = − [illegible] " }

Magnet No [illegible] suspended.

One Division of Scale = 1[illegible]7

Thermometer No [illegible]

	h m	Semi-arc of Vibration	d		Temperature of Magnet	
† Mean Time of Experiment =	5 56	At Commencement ‡ (a)	31	= 44.0	29 35	
† Error of Chronometer	29	At Middle			29 05	t = 29.0 § + 0.1 = 29.1
† True L. M. T. of Experiment =	5 27	At End (a)	11	= 15.0	29 20	
‖ Reading of Vertical Scale =	23.9 divisions					

Approximate Time of Vibration

h m s

Time of 18 vibrations =

" 9 " = 24.7

Torsion Coefficient

Reading of torsion head	Circle turned	Scale Reading	Means of pairs of	Difference	Sum of quantities in last col
		d	d	d	d
	0				Value of 90° of torsion
	+ 180				$\frac{\text{Sum}}{4}$ =
	0				
	− 180				72
	0				

TIME of VIBRATION

Commencing on the magnet's Right					Commencing on the magnet's Left				
No of Vibs	Time of cross wire passing scale centre (h m sec)	No of Vibs	Time of cross wire passing scale centre (m sec)	Time of 162 Vibns (m sec)	No of Vibs	Time of cross wire passing scale centre (h m sec)	No of Vibs	Time of cross wire passing scale centre (m sec)	Time of 162 Vibns (m sec)
0	5 50 21 70	162	56 56 30	6 34 60	9	5 50 46 [illegible]	171	57 20 45	6 34 45
18	51 11 10	180	57 45 65	55	27	51 35 80	189	58 10 30	50
36	52 00 45	198	58 34 95	50	45	52 25 [illegible]	207	58 59 60	45
54	52 49 75	216	59 24 20	45	63	53 14 40	225	59 48 90	50
72	53 39 10	234	60 3 60	50	81	54 3 75	243	60 38 25	50
90	54 28 35	252	61 2 90	55	99	54 53 05	261	61 27 50	45
108	55 17 70	270	61 52 15	45	117	55 42 30	279	62 16 80	50
Diff for 36	1 39 75		Sum =	3 60	Diff for 54	1 38 65		Sum =	3 35
162 at	56 56 45		Mean (1) =	6 34 51.4	171 at	57 20 95		Mean (2) =	6 34 47.1

$$T_1 = T_0 \left\{ 1 - \frac{s}{86400} - \frac{aa}{16} \right\} \qquad T^2 = T_1^2 \left\{ 1 + \frac{F}{mH} - Q(t - t_0) + \mu \frac{H_1}{m_1} \right\} \qquad mH = \frac{\pi^2 K}{T^2}$$

(Table I) $1 - \frac{s}{86400}$ = [illegible]

(Table II) $- \frac{aa}{16}$ = −

$1 - \frac{s}{86400} - \frac{aa}{16}$ =

(Table III) $1 + \frac{F}{mH}$ = 1.00013

(Table V) $- Q(t - t_0)$ = − .01186

** $+ \mu \div \frac{m_1}{H_1}$ = + .00254

$\left\{ 1 + \frac{F}{mH} - Q(t-t_0) + \mu \div \frac{m_1}{H_1} \right\}$ = .99111

(See Constants) μ Log = .90956

(From Deflection Obns) $\frac{m_1}{H_1}$ Log = 2.50514

** $\mu \div \frac{m_1}{H_1}$ = .00254 Log = $\bar{3}$.40442

(a) ½ {Mean (1) + Mean (2)} = 394.493 ¶ sec Log = 2.596039 } 6 places

(b) Number of Vibrations = 162 Log = 2.158363 }

(a) ÷ (b) = T_0 Log = .43768 5 places

Log = $\bar{1}$

T_1 Log =

T_1^2 Log = .87536

Log = $\bar{1}$.99612

T^2 Log = .87148

(Table VI) $\pi^2 K$ Log = 3.37075

$mH = \frac{\pi^2 K}{T^2}$ Log = 2.49927

(From Deflection Obns) $\frac{m}{H}$ Log =

$mH \div \frac{m}{H} = H^2$ Log =

H = Log =

$mH \times \frac{m}{H} = m^2$ Log =

m = Log =

* From table II. † To nearest ¼ minute

‡ The semi-arc at commencement should be from 35′ to 40′ if high power eyepiece is used or from 60′ to 70′ if the low power is used

‖ The telescope bubble must be in the centre of its run and the magnet swinging freely when this reading is taken.

§ Correction from Table VII. ¶ To 3 places of decimals

Computed and Compared by ________ *and* ________

Observed by ________

Recorded by ________

[illegible]

Magnetic No. 8

Survey of India.

Original / Duplicate

Determination of ANGLE of DEFLECTION and $\frac{m}{H}$ with Magnetometer No. 1 *by* T Cooke [illegible] *Date* 12 4 02

Station Rawalpindi { *Lat.* 33° 34' 21" *Long.* 73 4 24 } L.M.T. of observation ¶ 5 h 0 m

Chrn. No. 6343 *slow / fast* 29 *Mins.* *Therm. No.* 1 *Zero reading (i.e. Centre of Scale)* 50 d.

Magnet No 10' *deflecting.* *One Scale divn.** 1' 4C7

Deflecting Magnet: Dist in cms	N end	Temp Cent °	Time h m	Readings of Verniers ° ' "	Mean of Verniers ° ' "	Scale reading	† Corrn to zero reading ' "	No. of Obsn	Corrected Circle Reading ° ' "	Means and differences
East										Mean of 5 and 8
40	E.	29.95	5 20	136 55 35 / 55 40	136 55 38	48 05	+ 2 45	1	136 58 23	165 28 34
										Mean of 6 and 7
40	W	29.95	5 23	125 40 5 / 40 0	125 40 3	48 0	+ 2 49	2	125 42 52	97 2 22
										Difference
30	W	29.9	5 25	117 49 10 / 49 30	117 49 21	48 0	+ 2 49	3	117 52 9	68 16 12
										Half Diff = $u_{22\cdot5}$
30	E	29.05	5 27	144 44 20 / 44 40	144 44 30	48 0	+ 2 49	4	144 47 0	34 8 6
										Mean of 4 and 9
22.5	E	29.8	5 30	164 52 30 / 52 50	164 52 40	49 05	+ 2 45	5	164 55 25	144 56 25
										Mean of 3 and 10
22.5	W	29.7	5 33	97 35 10 / 35 30	97 35 20	48 0	+ 2 49	6	97 38 9	117 45 2
West										Difference
22.5	W	29.5	5 36	96 43 40 / 43 50	96 43 45	48 0	+ 2 49	7	96 46 34	27 11 23
										Half Diff u_{30}
22.5	E	29.4	5 37	165 58 45 / 59 0	165 58 53	48 0	+ 2 49	8	165 61 42	13 35 42
										Mean of 1 and 12
30	E	29.25	5 39	145 2 40 / 2 50	145 2 45	48 05	+ 2 45	9	145 5 30	137 1 3
										Mean of 2 and 11
30	W	29.25	5 42	117 35 0 / 35 10	117 35 5	48 0	+ 2 49	10	117 37 54	125 40 35
										Difference
40	W	29.2	5 46	125 35 20 / 35 35	125 35 28	48 0	+ 2 49	11	1[illegible] 38 17	11 20 28
										Half Diff = u_{40}
40	E	29.45	5 45	137 0 45 / 0 60	137 0 53	48 0	+ 2 49	12	137 3 42	5 40 14

Mean Temp. 29.57 | 5 33 = Mean of times to nearest ¼ minute

Correction‡ – ·0 | 4 : 29 = Error of Chrn " "

T. M Temp. 29.57 | 5 : 2 = ¶ True L M T " "

Abstract (° ' ")

$u_{22\cdot5}$ = 34 8 6

u_{30} = 13 35 42

u_{40} = 5 40 14

Computation of P

I $P = 2604{\cdot}4(\log A_1 - \log A_2) - 10955(\log A_1 - \log A_2)^2 = a - b$

log A_1 = 3 51047 (r = 22 5 cms)

log A_2 = 3 50767 (r = 30 cms.)

log A_1 – log A_2 = 280 (1)

2604 4 log = 3 41566 0

§ (1) log = $\bar{3}$ 44716

a log = 0 87276 a = 7·460

10955 log = 1 03968

(1)² log = $\bar{6}$ 89432

b log = $\bar{2}$ 93395 b = ·086

(From 22 5 and 30 cms) $P = a - b$ = 7·374

II $P = 4786{\cdot}7(\log A_2 - \log A_3) - 19176(\log A_2 - \log A_3)^2 = c - d$

log A_2 = 3 50767 (r = 30 cms)

log A_3 = 3 50601 (r = 40 cms)

log A_2 – log A_3 = 166 (2)

4786 7 log = 3 67548

§ (2) log = $\bar{3}$ 22011

c log = 89559 c = 7·863

19176 log = 4 28951

(2)² log = $\bar{6}$ 44022

d log = $\bar{2}$ 72973 d = ·054

(From 30 and 40 cms) $P = c - d$ = 7·809

NOTE.—Keep a, b, c and d to 3 places of decimals

* From Table II

† The correction is $\mp$ according as the scale reading is greater / less than the zero reading

‡ Correction from Table VII

§ Log A_1 log A_2 and log A_3 are to be treated as natural numbers and the log of their diff entered

Computation of $\frac{m}{H}$.

$$\frac{m}{H_1} = \tfrac{1}{2} r^3 \sin u \left\{1 - \frac{2\mu}{r^2} - Q(t - t_0)\right\}^{-1} = A; \qquad \frac{m}{H} = \frac{m}{H_1}\left(1 - \frac{P}{r^2}\right)$$

	r = 22 5	r = 30	r = 40
Table IV … … $1 - \frac{2\mu}{r^2}$ =	·99857	·99940	99975
Table V … $- Q(t - t_0)$ =	– ·01172	– ·01172	– ·01172
$1 - \frac{2\mu}{r^2} - Q(t - t_0)$ =	·98686	98[illegible]68	98803
$\left\{1 - \frac{2\mu}{r^2} - Q(t - t_0)\right\}$ log. =	$\bar{1}$·99425	$\bar{1}$ 99462	$\bar{1}$·99477
$\left\{1 - \frac{2\mu}{r^2} - Q(t - t_0)\right\}^{-1}$ log. =	·00575	·00538	·00523
Table VI … … $\frac{1}{2}r^3$ log =	3·75565	4·13112	4·50599
Sin u log. =	$\bar{1}$·74907	$\bar{1}$·37117	$\bar{2}$·99479
Sum or log. A or log $\frac{m}{H_1}$ =	3·51047	3·50767	3·50601
$1 - \frac{P}{r^2}$ ¤ log. =	$\bar{1}$·99362	$\bar{1}$·99642	$\bar{1}$·99799
$\frac{m}{H}$ log. =	3·50409 ⁑	3 50409	3 50400

¤ The mean value of P (from 22·5 and 30 c ms) derived from the season's observations is used.

Observed by ______

Computed by ______

Checked by ______

Computation of m and H

From 1st set of Vibrations L M T = 16 h 37 m

(From Vibration form) mH log = 2 49929

$\frac{m}{H}$ log = 3·50409

$mH \div \frac{m}{H} = H^2$ log = $\bar{2}$ 99520

H = ·31449 log = $\bar{1}$ 49760

$mH \times \frac{m}{H} = m^2$ log = 6·00338

m = 1003 90 log = 3 00169

From 2nd set of Vibrations. L. M. T = 5 h 27 m

(From Vibration form) mH log = 2 49927

$\frac{m}{H}$ ⁑ log = 3·50409

$mH \div \frac{m}{H} = H^2$ log = $\bar{2}$·99518

H = ·31448 log = $\bar{1}$·49759

$mH \times \frac{m}{H} = m^2$ log. = 6·00336

m = 1003·88 log. = 3·00168

⁑ The value of $\frac{m}{H}$ derived from the deflection angle u_{30} is to be used, and not the mean value derived from the three angles.

Survey of India.

MAGNETIC DIP.

Determination of Magnetic Meridian.

Station *Bahawalpur* Date *6th April 02*

Circle No. *139* Needle No. *1*

Face of Needle	Face of Instr.	Lower End of Needle intersected ° ′	Upper End of Needle intersected ° ′	Mean ° ′
Face of Needle to Face of Instrument	South	76 49	77 5	76 57
			Mean = a =	
	North			
			Mean = a' =	
Face of Needle Reversed	North			
			Mean = a'' =	
	South			
			Mean = a''' =	
			a'' =	
			a' =	
			a =	
			Sum =	
			Mean of Means = α =	
			* Setting of Azimuth Circle = 90° + α =	

Mean of times to nearest ¼ minute = 12 h 51 m

Error of Chronr. " " = + 34

True L. M. T. " " = 12 17

Intersections of R. M. † ° ′ 5 : 22 / 5 : 21 / :

Mean = 5 : 22 (a)

Angle between R. M. and Magnetic S ‡ = +161 : 39 (b)

Sum § = 167 : 1 (c)

77·1 No corrn. Jy. A. A. D. F.

† These intersections are made with the sights and must never be omitted.

‡ (b) is extracted (to the nearest minute) from the Declination Observations of the same date. It cannot exceed 180° and is ± according as the R.M. is $\frac{\text{East}}{\text{West}}$ of the Magnetic Meridian. If it is negative and numerically greater than (a), the latter must be increased by 360°, so that their sum (c) shall always be positive.

§ If the angle (c) be greater than 90°, it must be reduced by the largest multiple of 90° it contains, in order to obtain the "Setting of Azimuth Circle" to be entered on the opposite page.

Observed by ______________________

Trigl. Branch, Dehra Dún, 9-7-09—200,

No. 7, S. T. B.—Feb. 04.—300.

Magnetic No. 4.

Survey of India.

~~Original~~
Duplicate

Determination of Dip *with Circle No.* 139 *by* Dover *Date* 6th April 1902

Station Bahawalpur No 1 { Lat. 29° 24' 23" ; Long. 71° 40' 35" }

Needle No. 1 ◻ Mean Dip = 41° : 30'·1 at 12h 17m L.M.T. ¶

*Setting of Azimuth Circle 76° 57' Chron. No. 6543 ~~slow~~ fast 34m - 12 Secs.

Time 12h 15m to 12h 24m Time 1h 17m to 1h 25m

Face of Needle	Face of Instr.	Poles Direct, a dipping: Lower End	Upper End	Mean	Poles Reversed, B dipping: Lower End	Upper End	Mean
Face of Needle to Face of Instrument	East	41° 22'	41° 50'	41° 36'	41° 12'	41° 37'	41° 24'·5
		41 20	41 48	41 34	41 12	41 36	41 24·0
			Sum =			Sum =	
			Mean = a =	41 35·		Mean = b =	41 24·3
	West	41 29	41 32	41 30·5	41 21	41 29	41 25·0
		41 32	41 35	41 33·5	41 21	41 29	41 25·0
			Sum =			Sum =	
			Mean = a′ =	41 32·0		Mean = b′ =	41 25·0
Face of Needle Reversed	West	41 30	41 37	41 33·5	41 18	41 20	41 19·0
		41 32	41 39	41 35·5	41 19	41 22	41 20·5
			Sum =			Sum =	
			Mean = a″ =	41 34·5		Mean = b″ =	41 19·8
	East	41 23	41 46	41 34·5	41 15	41 42	41 28·5
		41 21	41 44	32·5	41 14	41 42	41 28·0
			Sum =			Sum =	
			Mean = a‴ =	41 33·5		Mean = b‴ =	41 28·3
			a″ =	41 34·5		b″ =	41 19·8
			a′ =	41 32·0		b′ =	41 25·0
			a =	41 35·0		b =	41 24·3
			Sum =	135·0		Sum =	97·4
			Mean of Means = α =	41 33·8		Mean of Means = β =	41 24·4
						Do. do. = α =	41 33·8
						Dip = $\frac{\alpha+\beta}{2}$ =	41 29·1

¶ When two needles are used, the observations must be taken in the following order:—1. First needle, Poles Direct. 2. Second needle, Poles Direct. 3. Second needle, Poles Reversed. 4. First needle, Poles Reversed. The Polarity of both needles is reversed before commencing 3.

Computed and compared by ________

Photo. & L. O., Calcutta.

Magnetic No. 5. **Survey of India.** Original

Magnetometer No. 10 *Computation of Log π^2K* Date 16.10.03

Magnet No. 10 Rate of Sidereal Clock (s) = ± 1·865 sec.

Inertia bar No. 2 25.26.27.26

l_0 = 9·285 cms
d_0 = 1·018 "
M = 63·889 gms
From Constants Set No. 11 B.B.

Vibration without bar				Vibration with bar			
Mean Torsion *	Temperature (t)		Semi-arc	Mean Torsion *	Temperature (t)		Semi-arc
2·07	I	28·08	Mean a = 48′	2·57	II	28·23	Mean a = 48′
	IV	28·38	Mean a_1 = 27		III	28·28	" a_1 = 35
				Mean Temperature = t_1 = 28·26			

Formulæ $[T]_1 = [T]_0 \left\{1 - \frac{s}{86400} - \frac{aa_1}{16}\right\}$; $[T_1]_1 = [T_1]_0 \left\{1 - \frac{s}{86400} - \frac{aa_1}{16}\right\}$

	I	IV	II	III
Table I . . . . $1 - \frac{s}{86400}$	·999978	·999978	·999978	·999978
" II . . . . $-\frac{aa_1}{16}$	− · 7	− · 7	− · 9	− · 9
$\left\{1 - \frac{s}{86400} - \frac{aa_1}{16}\right\}$	·999971	·999971	·999969	·999969
ditto log	$\bar{1}$·999987	$\bar{1}$·999987	$\bar{1}$·999987	$\bar{1}$·999987
factor † log	$\bar{1}$·998813	$\bar{1}$·998813	$\bar{1}$·998813	$\bar{1}$·998813
$[T]_0$ log	·473781	·473821	·698383	·698405
Sum = $[T]_1$ log	·472581	·472621	·697183	·697205

Formulæ $T^2 = [T]_1^2 \left\{1 + \frac{F}{mH} - Q(t - t_1)\right\}$; $T_1^2 = [T_1]_1^2 \left\{1 + \frac{F}{mH} - Q(t - t_1)\right\}$

	I	IV	II	III
Table III . . . . $1 + \frac{F}{mH}$	1·000384	1·000384	1·000476	1·000476
" V . . . . $-Q(t-t_1)$	+ · 81	− · 54	+ · 14	− · 9
$\left\{1 - \frac{F}{mH} - Q(t-t_1)\right\}$	1·000465	1·000330	1·000490	1·000467
ditto log	·000202	·000143	·000213	·000203
from above $[T]_1^2$ log	·945162	·945242	1·394366	1·394410
Sum = T^2 log	·945364	·945385	1·394579	1·394613
Mean T^2 log		·945375	Mean T_1^2 log	1·394596
$T_1^2 - T^2$ log		1·203851	T_1^2	24·8082
$\frac{T^2}{T_1^2 - T^2}$ = B log		$\bar{1}$·741524	T^2	8·8181
			$T_1^2 - T^2$	15·9901

(4 places)

Formula $\pi^2K\left\{1+\beta t_1+\beta_1 t_1^2\right\}^2 = M\frac{T^2}{T_1^2-T^2}\left(\frac{l_0^2}{12}-\frac{d_0^2}{16}\right)\left\{1+\alpha t_1+\alpha_1 t_1^2\right\}^2\pi^2$ or $\pi^2K \times A^2 = M \times B \times C \times D^2 \times \pi^2$

l_0 . . . . . . log	·967782	d_0 . . . . . . log	·007748	M log	1·805426
l_0^2 . . . . . . log	1·935564	d_0^2 . . . . . . log	·015496	B log	$\bar{1}$·741524
12 . . . . . . log	1·079181	16 . . . . . . log	1·204120	C log	·860281
$\frac{l_0^2}{12}$ . . . . . . log	·856383	$\frac{d_0^2}{16}$ . . . . . . log	$\bar{2}$·811376	Table VIII D^2 log	430
		$\frac{d_0^2}{16}$	·06477	π^2 log	0·994300
		$\frac{l_0^2}{12}$	7·18428	Sum = $\pi^2K \times A^2$ log	3·401961
		$\frac{l_0^2}{12} + \frac{d_0^2}{16}$ = C	7·24905	Table VIII A^2 log	276
			(5 places)	π^2K log	3·401685

* In a series of observations, use the mean torsion coefficient derived from all observations taken with the same suspension.
† Factor for converting from sidereal to mean time.

Observed by Shri Shar

Computed and compared by

Trigl. Branch, Dehra Dun, 5-10-03—500.
No. 7.A.C.S.—Feb. 04—250.

Photo. S.I.O., Calcutta.

Table for computing P.

From 22·5 and 30 cms.

Argument log. A_1 − log. A_2 where

$A_1 = \frac{M_1}{H_1}$ from 22·5 cms.

$A_2 = \frac{M_1}{H_1}$ from 30 cms.

$10^{-5} \times$	0	1	2	3	4	5	6	7	8	9
100										
110										
120										
130										
140										
150	3·97	4·00	4·02	4·05	4·08	4·10	4·13	4·16	4·18	4·21
160	4·24	4·26	4·29	4·31	4·34	4·37	4·39	4·42	4·45	4·47
170	4·50	4·52	4·55	4·58	4·60	4·63	4·66	4·68	4·71	4·73
180	4·76	4·79	4·81	4·84	4·87	4·89	4·92	4·94	4·97	5·00
190	5·02	5·05	5·08	5·10	5·13	5·15	5·18	5·21	5·23	5·26
200	5·29	5·31	5·34	5·36	5·39	5·42	5·44	5·47	5·49	5·52
210	5·55	5·57	5·60	5·63	5·65	5·68	5·70	5·73	5·76	5·78
220	5·81	5·83	5·86	5·89	5·91	5·94	5·97	5·99	6·02	6·04
230	6·07	6·10	6·12	6·15	6·17	6·20	6·23	6·25	6·28	6·31
240	6·33	6·36	6·38	6·41	6·44	6·46	6·49	6·51	6·54	6·57
250	6·59	6·62	6·64	6·67	6·70	6·72	6·75	6·78	6·80	6·83
260	6·85	6·88	6·91	6·93	6·96	6·98	7·01	7·04	7·06	7·09
270	7·11	7·14	7·17	7·19	7·22	7·24	7·27	7·30	7·32	7·35
280	7·37	7·40	7·43	7·45	7·48	7·50	7·53	7·56	7·58	7·61
290	7·63	7·66	7·69	7·71	7·74	7·76	7·79	7·82	7·84	7·87
300	7·89	7·92	7·95	7·97	8·00	8·02	8·05	8·08	8·10	8·13
310	8·15	8·18	8·21	8·23	8·26	8·28	8·31	8·34	8·36	8·39
320	8·41	8·44	8·47	8·49	8·52	8·54	8·57	8·60	8·62	8·65
330	8·67	8·70	8·73	8·75	8·78	8·80	8·83	8·85	8·88	8·91
340	8·93	8·96	8·98	9·01	9·04	9·06	9·09	9·11	9·14	9·17
350	9·19	9·22	9·24	9·27	9·29	9·32	9·35	9·37	9·40	9·42
360	9·45	9·48	9·50	9·53	9·55	9·58	9·60	9·63	9·66	9·68
370	9·71	9·73	9·76	9·79	9·81	9·84	9·86	9·89	9·91	9·94
380	9·97	9·99	10·02	10·04	10·07	10·10	10·12	10·15	10·17	10·20
390	10·22	10·25	10·28	10·30	10·33	10·35	10·38	10·41	10·43	10·46
400	10·48									

From 30 and 40 cms.

Argument log. A_2 − log. A_3 where

$A_2 = \frac{M_1}{H_1}$ from 30 cms.

$A_3 = \frac{M_1}{H_1}$ from 40 cms.

$10^{-5} \times$	0	1	2	3	4	5	6	7	8	9	
100	4·72	4·76	4·81	4·86	4·91	4·95	5·00	5·05	5·09	5·14	100
110	5·19	5·23	5·28	5·33	5·37	5·42	5·47	5·52	5·56	5·61	110
120	5·66	5·70	5·75	5·80	5·84	5·89	5·94	5·98	6·03	6·08	120
130	6·12	6·17	6·22	6·27	6·31	6·36	6·41	6·45	6·50	6·55	130
140	6·59	6·64	6·69	6·73	6·78	6·83	6·87	6·92	6·97	7·01	140
150	7·06	7·11	7·15	7·20	7·25	7·30	7·34	7·39	7·44	7·48	150
160	7·53	7·58	7·62	7·67	7·72	7·76	7·81	7·86	7·90	7·95	160
170	8·00	8·04	8·09	8·14	8·18	8·23	8·28	8·32	8·37	8·42	170
180	8·46	8·51	8·56	8·60	8·65	8·70	8·74	8·79	8·84	8·88	180
190	8·93	8·98	9·02	9·07	9·12	9·16	9·21	9·26	9·30	9·35	190
200	9·40	9·44	9·49	9·54	9·58	9·63	9·68	9·72	9·77	9·81	200
210	9·86	9·91	9·95	10·00	10·05	10·09	10·14	10·19	10·23	10·28	210
220	10·33	10·37	10·42	10·47	10·51	10·56	10·61	10·65	10·70	10·75	220
230	10·79	10·84	10·88	10·93	10·98	11·02	11·07	11·12	11·16	11·21	230
240	11·26	11·30	11·35	11·40	11·44	11·49	11·53	11·58	11·63	11·67	240
250	11·72	11·77	11·81	11·86	11·91	11·95	12·00	12·04	12·09	12·14	250
260	12·18	12·23	12·28	12·32	12·37	12·42	12·46	12·51	12·55	12·60	260
270	12·65	12·69	12·74	12·79	12·83	12·88	12·92	12·97	13·02	13·06	270
280	13·11	13·16	13·20	13·25	13·30	13·34	13·39	13·43	13·48	13·53	280
290	13·57	13·62	13·67	13·71	13·76	13·80	13·85	13·90	13·94	13·99	290
300	14·03										300
310											310
320											320
330											330
340											340
350											350
360											360
370											370
380											380
390											390
400											400

IV

TIDAL AND LEVELLING OPERATIONS FOR THE YEAR 1901-02.

Extract from the Narrative Report of Captain H. L Crosthwait, R.E., and E. J. Connor, Esq., in charge No. 25 Party (Tidal and Levelling), Season 1901-02.

TIDAL OPERATIONS.

15. Tidal operations, including the registration at 13 ports of tidal curves by means of self-registering gauges, the reduction by Harmonic Analysis of tidal observations for 1901 at 12 ports, and the publication of tide-tables giving the predicted times and heights of every high and low-water for the year 1902 for 39 ports, have been carried on, as usual, during the year ending 30th September 1902

16. Tabulated details have been given below of the 42 ports at which tidal observations have been, and are still being taken; 13 are now working, of which one was started during the year; and 29 have been closed on completion of their registrations. The stations in italics are permanent; the others are minor, at which only five years' registrations are required :—

LIST.

	Stations.	Automatic or personal observations.	Date of commencement of observations.	Date of closing of observations.	No. of years of observations.	Remarks.
1	Suez	Automatic	1897	Still working	5	To be closed.
2	Perim	Ditto	1898	Ditto	4	To be closed.
3	*Aden*	Ditto	1879	Ditto	22	
4	Maskat	Ditto	1893	1898	5	
5	Bushire	Ditto	1892	1901	8	
6	*Karachi*	Ditto	1881	Still working	21	
7	Hanstal	Ditto	1874	1875	1	Tide-tables not published.
8	Navinár	Ditto	1874	1875	1	
9	Okha Point	Ditto	1874	1875	1	
10	Porbandar	Personal.	1893	1894	2	
10A	Porbandar	Automatic	1898	Still working	4	With certain interruptions.
11	Port Albert Victor (Káthiwadar).	Personal.	1881	1882	1	
11A	Port Albert Victor (Káthiwadar).	Automatic	1900	Still working	2	
12	Bhávnagar	Ditto	1889	1894	5	
13	*Bombay* (Apollo Bandar)	Ditto	1878	Still working	24	
14	Bombay (Prince's Dock)	Ditto	1888	Ditto	14	Property of Port Trust.
15	Mormugáo (Goa)	Ditto	1884	1889	5	
16	Kárwár	Ditto	1878	1883	5	
17	Beypore	Ditto	1878	1884	6	
18	Cochin	Ditto	1886	1892	6	
19	Tuticorin	Ditto	1888	1893	5	
20	Minicoy	Ditto	1891	1896	5	
21	Galle	Ditto	1884	1890	6	
22	Colombo	Ditto	1884	1890	6	
23	Trincomalee	Automatic	1890	1896	6	
24	Pámbán Pass	Ditto	1878	1882	4	
25	Negapatam	Ditto	1881	1888	6	Year 1884-85 is excluded.
26	*Madras*	Ditto	1880	1890	10 } 17	
			restarted 1895	Still working	7	
27	Cocanada	Ditto	1886	1891	5	

LIST—*contd.*

	Stations.	Automatic or personal observations.	Date of commencement of observations.	Date of closing of observations.	No. of years of observations.	Remarks.
28	Vizagapatam	Automatic	1879	1885	6	
29	False Point	Ditto	1881	1885	4	
30	Dublat (Saugor Island)	Ditto	1881	1886	5	
31	Diamond Harbour	Ditto	1881	1886	5	
32	*Kidderpore*	Ditto	1881	Still working	21	
33	Chittagong	Ditto	1886	1891	5	
34	Akyab	Ditto	1887	1892	5	
35	Diamond Island	Ditto	1895	1899	5	
36	Bassein (Burma)	Ditto	1902	Newly started.	...	Started this year
37	Elephant Point	Ditto	1880 restarted 1884	1881 1888	1 } 6 5	
38	*Rangoon*	Ditto	1880	Still working	22	
39	Amherst	Ditto	1880	1886	6	
40	Moulmein	Ditto	1880	1886	6	
41	Mergui	Ditto	1889	1894	5	
42	*Port Blair*	Ditto	1880	Still working	22	

17. Personal tidal observations to graduated staves were also taken during daylight at Bhávnagar, Chittagong, Akyab and Moulmein, to compare with corresponding predicted times and heights of high and low-water.

18. The newly built tidal observatory at Bassein in Burma was started working on the 1st January 1902. The Suez and Perim observatories will be closed early next year.

19. The Tidal Observatories have on the whole worked very satisfactorily throughout the year and the Survey Department is much indebted to the Local Port Officers and others who so kindly supervised the working of the instruments.

Such points of interest as have occurred during the year are touched on below.

23. *Karachi.*—The tidal record has been most satisfactory and interesting, as the highest tide, registered during the last 34 years, occurred during the cyclone in June 1902. The two anemographs at Karachi, the usual small one, belonging to the tidal observatory and the large one, belonging to the Port Trust, failed to record in the cyclone in June 1902.

24. *Porbandar.*—This minor observatory has again a faulty record. The pipe having repeatedly got choked, Captain Crosthwait, R.E., had a length of 104 feet of new pipes of 6-inch diameter fitted, instead of the old pipes of 9-inch diameter, in January 1902. Three cyclones visited Porbandar in May, June and July 1902, respectively. The pipe communication was interrupted by the cyclone in May. The observations were restarted on the 7th of June, after flushing and cleaning the cylinder.

25. *Port Albert Victor* (Káthiwadar).—So far the observations at this minor observatory have been satisfactory, but whether they will continue so or not is doubtful, owing to the changes reported to be taking place in the shoals outside the creek, which, I am informed, is silting. The sundial pillar was destroyed in July 1902, by the Sea.

When the observatory was started working at Port Albert Victor in January 1900, it was noticed that the water percolated very fast through the porous circumjacent rock, in which the well has been cut. The tidal observations are, therefore, more or less vitiated as the water gets into the well faster than it gets out. A comparison of the actual and predicted times of high and low-waters for 1901, shows that the vitiation is greatest at neap tides. The State Engineer, Bhávnagar, has been addressed on the subject, and he has been asked whether an iron cylinder can be prepared and fitted into the well at the next annual inspection at the cost of the Bhávnagar State; or preferably, whether he can have the well dressed at once with a skin of cement to prevent percolation.

30. *Bassein.*—(Burma).—This newly built minor tidal observatory was started working, on one-third the natural scale, on the 1st January 1902.

The bench-mark of reference is $\overset{\text{G.T.S.}}{\underset{\text{B.M.}}{\bullet}}$ A. It consists of an iron plug, 2 inches in diameter, and 3 inches above the surface of the step leading to the Port and

Customs Offices at Bassein. The letters have been cut in the cement. Another bench-mark (the high-water flood mark) is an iron bar let into a block of masonry close to the Rangoon pier on the Strand Road at Bassein. These two bench-marks were connected by spirit-levelling, and were found to be 5·900 feet and 7·045 feet, respectively, below the bed-plate of the tide-gauge.

In the great cyclone of the 6th May 1902, the Port Officer remarked that "the northerly wind seems to have blown the water out of the river." No injury, however, was sustained.

34. The year has been very stormy; and it is most satisfactory to report that none of the tidal observatories were wrecked by the destructive cyclones, which did much damage elsewhere.

35. The tidal observations for a year at twelve stations have been reduced; and the tabulated values of the tidal constants thus derived are appended.

VALUES OF THE TIDAL CONSTANTS, SUEZ, 1901.

The following are the amplitudes (R) and epochs (ζ) deduced from the 1901 Observations at Suez; and also the *mean* values of the amplitudes (H) and of the epochs (κ) for each particular tide evaluated from the 1901 Observations:—

Short Period Tides.

A_0=4·400 feet.

S_1	H = R =	·091	M_6	R =	·011	Q_1	R =	·006	T_2	R =	·036
	κ = ζ =	68°·45		ζ =	128°·93		ζ =	31°·14		ζ =	313°·29
S_2	H = R =	·456		H =	·010		H =	·006		H =	·036
	κ = ζ =	9°·02		κ =	65°·09		κ =	251°·46		κ =	314°·18
S_4	H = R =	·002	M_8	R =	·003	L_2	R =	·077	$(MS)_4$	R =	·015
	κ = ζ =	271°·35		ζ =	165°·96		ζ =	67°·97		ζ =	105°·84
S_6	H = R =	·002		H =	·002		H =	·074		H =	·015
	κ = ζ =	217°·41		κ =	200°·84		κ =	12°·39		κ =	204°·56
S_8	H = R =	·001	O_1	R =	·040	N_2	R =	·604	$(2SM)_2$	R =	·012
	κ = ζ =	142°·13		ζ =	302°·77		ζ =	249°·37		ζ =	328°·62
				H =	·045		H =	·589		H =	·012
				κ =	199°·81		κ =	311°·37		κ =	229°·90
M_1	R =	·019	K_1	R =	·119	λ_2	R =	...	$2N_2$	R =	·133
	ζ =	39°·29		ζ =	346°·85		ζ =	...		ζ =	208°·27
	H =	·013		H =	·127		H =	...		H =	·130
	κ =	206°·16		κ =	184°·72		κ =	...		κ =	233°·56
M_2	R =	1·889	K_2	R =	·099	ν_2	R =	·143	$(M_2N)_4$	R =	·053
	ζ =	244°·48		ζ =	142°·61		ζ =	63°·44		ζ =	213°·32
	H =	1·844		H =	·119		H =	·139		H =	·051
	κ =	343°·20		κ =	357°·59		κ =	295°·96		κ =	14°·04
M_3	R =	·021	P_1	R =	·057	μ_2	R =	·090	$(M_2K_1)_3$	R =	·044
	ζ =	82°·77		ζ =	324°·79		ζ =	39°·01		ζ =	178°·68
	H =	·021		H =	·057		H =	·086		H =	·046
	κ =	50°·85		κ =	134°·44		κ =	236°·45		κ =	115°·26
M_4	R =	·027	J_1	R =	·013	R_2	R =	...	$(2M_2K_1)_3$	R =	·011
	ζ =	318°·84		ζ =	14°·36		ζ =	...		ζ =	66°·31
	H =	·025		H =	·014		H =	...		H =	·011
	κ =	156°·28		κ =	252°·76		κ =	...		κ =	65°·89

Long Period Tides.

	R	ζ	H	κ
Lunar Monthly Tide	·100	311°·86	·092	348°·58
" Fortnightly "	·028	44°·63	·036	169°·28
Luni-Solar " "	·041	261°·94	·040	163°·22
Solar-Annual "	·500	32°·06	·500	312°·42
" Semi-Annual "	·114	274°·96	·114	115°·67

VALUES OF THE TIDAL CONSTANTS, PERIM, 1901.

The following are the amplitudes (R) and epochs (ζ) deduced from the 1901 Observations at Perim; and also the *mean* values of the amplitudes (H) and of the epochs (κ) for each particular tide evaluated from the 1901 Observations:—

Short Period Tides.

A_0=5·407 feet.

Tide			Tide			Tide			Tide		
S_1	H = R =	·088	M_6	R =	·008	Q_1	R =	·104	T_2	R =	·041
	κ = ζ =	148°·97		ζ =	62°·74		ζ =	164°·56		ζ =	197°·06
S_2	H = R =	·561		H =	·008		H =	·116		H =	·041
	κ = ζ =	243°·07		κ =	1°·11		κ =	26°·04		κ =	197°·98
S_4	H = R =	·004	M_8	R =	·000	L_2	R =	·042	$(MS)_4$	R =	·012
	κ = ζ =	341°·57		ζ =	108°·44		ζ =	248°·33		ζ =	336°·48
S_6	H = R =	·007		H =	·000		H =	·041		H =	·012
	κ = ζ =	225°·55		κ =	146°·26		κ =	193°·08		κ =	75°·94
S_8	H = R =	·003	O_1	R =	·525	N_2	R =	·352	$(2SM)_2$	R =	·025
	κ = ζ =	30°·58		ζ =	138°·52		ζ =	163°·93		ζ =	197°·42
				H =	·588		H =	·344		H =	·025
				κ =	36°·32		κ =	227°·06		κ =	97°·97
M_1	R =	·086	K_1	R =	1·070	λ_2	R =	...	$2N_2$	R =	·076
	ζ =	199°·93		ζ =	195°·36		ζ =	...		ζ =	163°·43
	H =	·062		H =	1·145		H =	...		H =	·074
	κ =	7°·17		κ =	33°·19		κ =	...		κ =	190°·24
M_2	R =	1·227	K_2	R =	·133	ν_2	R =	·090	$(M_2N)_4$	R =	·043
	ζ =	127°·25		ζ =	13°·27		ζ =	331°·44		ζ =	64°·99
	H =	1·198		H =	·158		H =	·088		H =	·041
	κ =	226°·70		κ =	228°·19		κ =	205°·05		κ =	227°·58
M_3	R =	·037	P_1	R =	·355	μ_2	R =	·069	$(M_2K_1)_3$	R =	·013
	ζ =	271°·26		ζ =	221°·17		ζ =	2°·69		ζ =	358°·66
	H =	·036		H =	·355		H =	·066		H =	·014
	κ =	240°·44		κ =	30°·84		κ =	201°·61		κ =	295°·94
M_4	R =	·023	J_1	R =	·073	R_2	R =	...	$(2M_2K_1)_3$	R =	·024
	ζ =	172°·58		ζ =	185°·55		ζ =	...		ζ =	250°·08
	H =	·022		H =	·080		H =	...		H =	·024
	κ =	11°·49		κ =	63°·52		κ =	...		κ =	251°·16

Long Period Tides.

	R	ζ	H	κ
Lunar Monthly Tide	·046	215°·07	·042	251°·39
" Fortnightly "	·036	271°·32	·046	35°·17
Luni-Solar " "	·027	233°·67	·026	134°·21
Solar-Annual "	·343	68°·55	·343	348°·87
" Semi-Annual "	·151	276°·66	·151	117°·30

Values of the Tidal Constants, Aden, 1901.

The following are the amplitudes (R) and epochs (ζ) deduced from the 1901 Observations at Aden; and also the *mean* values of the amplitudes (H) and of the epochs (κ) for each particular tide evaluated from the 1901 Observations :—

Short Period Tides.

A_0=5·837 feet.

S_1	H = R =	·089	M_6	R =	·008	Q_1	R =	·117	T_2	R =	·037
	κ = ζ =	168°·48		ζ =	23°·41		ζ =	166°·99		ζ =	229°·35
S_2	H = R =	·665		H =	·008		H =	·131		H =	·037
	κ = ζ =	244°·41		κ =	322°·10		κ =	28°·64		κ =	230°·27
S_4	H = R =	·004	M_8	R =	·001	L_2	R =	·049	$(MS)_4$	R =	·008
	κ = ζ =	308°·89		ζ =	276°·34		ζ =	255°·99		ζ =	75°·44
S_6	H = R =	·005		H =	·001		H =	·048		H =	·008
	κ = ζ =	209°·90		κ =	314°·60		κ =	200°·80		κ =	175°·01
S_8	H = R =	·002	O_1	R =	·584	N_2	R =	·441	$(2SM)_6$	R =	·028
	κ = ζ =	37°·57		ζ =	140°·76		ζ =	158°·03		ζ =	209°·48
				H =	·654		H =	·431		H =	·027
				κ =	38°·68		κ =	221°·33		κ =	109°·92
M_1	R =	·088	K_1	R =	1·221	λ_2	R =	...	$2N_2$	R =	·083
	ζ =	203°·04		ζ =	196°·90		ζ =	...		ζ =	153°·00
	H =	·063		H =	1·307		H =	...		H =	·081
	κ =	10°·33		κ =	34°·73		κ =	...		κ =	180°·03
M_2	R =	1·597	K_2	R =	·148	ν_2	R =	·112	$(M_2N)_4$	R =	·057
	ζ =	127°·19		ζ =	16°·78		ζ =	319°·08		ζ =	62°·97
	H =	1·559		H =	·177		H =	·109		H =	·055
	κ =	226°·76		κ =	231°·69		κ =	192°·84		κ =	225°·83
M_3	R =	·016	P_1	R =	·404	μ_2	R =	·076	$(M_2K_1)_3$	R =	·031
	ζ =	246°·04		ζ =	221°·11		ζ =	352°·89		ζ =	88°·69
	H =	·016		H =	·404		H =	·073		H =	·033
	κ =	215°·39		κ =	30°·79		κ =	192°·03		κ =	26°·08
M_4	R =	·008	J_1	R =	·076	R_2	R =	...	$(2M_2K_1)_5$	R =	·007
	ζ =	88°·55		ζ =	189°·85		ζ =	...		ζ =	293°·53
	H =	·008		H =	·084		H =	...		H =	·007
	κ =	287°·68		κ =	67°·76		κ =	...		κ =	294°·84

Long Period Tides.

	R	ζ	H	κ
Lunar Monthly Tide	·038	237°·60	·035	273°·87
,, Fortnightly ,, ...	·023	287°·60	·030	51°·33
Luni-Solar ,, ,, ...	·014	216°·46	·014	126°·89
Solar-Annual ,, ...	·328	77°·45	·328	357°·77
,, Semi-Annual ,, ...	·147	288°·76	·147	129°·40

Values of the Tidal Constants, Karachi, 1901.

The following are the amplitudes (R) and epochs (ζ) deduced from the 1901 Observations at Karachi; and also the *mean* values of the amplitudes (H) and of the epochs (κ) for each particular tide evaluated from the 1901 Observations :—

Short Period Tides.

A_0=7·151 feet.

S_1	H = R =	·090	M_6	R =	·048	Q_1	R =	·121	T_2	R =	·057
	κ = ζ =	178°·53		ζ =	259°·84		ζ =	175°·88		ζ =	284°·56
S_2	H = R =	·958		H =	·045		H =	·136		H =	·057
	κ = ζ =	323°·73		κ =	203°·00		κ =	39°·87		κ =	285°·54
S_4	H = R =	·012	M_8	R =	·003	L_2	R =	·070	$(MS)_4$	R =	·038
	κ = ζ =	23°·96		ζ =	265°·03		ζ =	332°·18		ζ =	218°·17
S_6	H = R =	·009		H =	·003		H =	·068		H =	·037
	κ = ζ =	282°·24		κ =	309°·25		κ =	277°·67		κ =	319°·22

Short Period Tides—contd.

S_8	H = R =	·002	O_1	R =	·588	N_2	R =	·638	$(2SM)_2$	R =	·025
	κ = ζ =	312°·71		ζ =	147°·84		ζ =	212°·59		ζ =	208°·89
				H =	·658		H =	·622		H =	·024
				κ =	47°·31		κ =	278°·17		κ =	107°·84
M_1	R =	·089	K_1	R =	1·234	λ_2	R =	...	$2N_2$	R =	·077
	ζ =	221°·71		ζ =	208°·39		ζ =	...		ζ =	189°·61
	H =	·064		H =	1·320		H =	...		H =	·075
	κ =	29°·74		κ =	46°·15		κ =	...		κ =	219°·73
M_2	R =	2·661	K_2	R =	·200	ν_2	R =	·176	$(M_2N)_4$	R =	·042
	ζ =	192°·64		ζ =	99°·86		ζ =	12°·25		ζ =	110°·69
	H =	2·598		H =	·238		H =	·172		H =	·040
	κ =	293°·70		κ =	314°·65		κ =	248°·20		κ =	277°·33
M_3	R =	·034	P_1	R =	·399	μ_2	R =	·083	$(M_2K_1)_3$	R =	·049
	ζ =	6°·63		ζ =	232°·28		ζ =	69°·33		ζ =	136°·60
	H =	·033		H =	·399		H =	·079		H =	·052
	κ =	338°·21		κ =	42°·03		κ =	271°·44		κ =	75°·42
M_4	R =	·014	J_1	R =	·076	R_2	R =	...	$(2M_2K_1)_3$	R =	·024
	ζ =	158°·90		ζ =	204°·25		ζ =	...		ζ =	347°·13
	H =	·014		H =	·084		H =	...		H =	·025
	κ =	1°·01		κ =	81°·30		κ =	...		κ =	351°·47

Long Period Tides.

	R	ζ	H	κ
Lunar Monthly Tide	·051	99°·63	·047	135°·09
„ Fortnightly „	·020	342°·16	·026	104°·29
Luni-Solar „ „	·016	41°·43	·016	300°·37
Solar-Annual „	·173	124°·62	·173	44°·88
„ „ Semi-Annual „	·140	281°·62	·140	122°·13

VALUES OF THE TIDAL CONSTANTS, PORBANDAR, 1900-1901.

The following are the amplitudes (R) and epochs (ζ) deduced from the 1900-1901 Observations at Porbandar; and also the *mean* values of the amplitudes (H) and of the epochs (κ) for each particular tide evaluated from the 1900-1901 Observations:—

Short Period Tides.

A_0=7·412 feet.

S_1	H=R=	·063	M_6	R=	·030	Q_1	R=	·100	T_2	R=	·024
	κ= ζ=	183°·21		ζ=	268°·94		ζ=	122°·04		ζ=	148°·00
S_2	H=R=	·782		H=	·029		H=	·107		H=	·024
	κ= ζ=	323°·45		κ=	307°·39		κ=	59°·34		κ=	353°·99
S_4	H=R=	·004	M_8	R=	·002	L_2	R=	·038	$(MS)_4$	R=	·029
	κ= ζ=	265°·49		ζ=	103°·00		ζ=	188°·65		ζ=	58°·93
S_6	H=R=	·010		H=	·002		H=	·044		H=	·028
	κ= ζ=	160°·87		κ=	274°·25		κ=	328°·78		κ=	191°·74
S_8	H=R=	·000	O_1	R=	·520	N_2	R=	·524	$(2SM)_2$	R=	·004
	κ= ζ=	161°·57		ζ=	270°·51		ζ=	341°·37		ζ=	277°·50
				H=	·561		H=	·514		H=	·004
				κ=	45°·66		κ=	276°·33		κ=	144°·68
M_1	R=	·093	K_1	R=	1·115	λ_2	R=	...	$2N_2$	R=	·057
	ζ=	263°·20		ζ=	49°·56		ζ=	...		ζ=	138°·10
	H=	·054		H=	1·166		H=	...		H=	·036
	κ=	72°·14		κ=	43°·13		κ=	...		κ=	235°·20
M_2	R=	2·176	K_2	R=	·169	ν_2	R=	·165	$(M_2N)_4$	R=	·062
	ζ=	159°·61		ζ=	161°·49		ζ=	153°·45		ζ=	92°·14
	H=	2·137		H=	·192		H=	·162		H=	·059
	κ=	292°·42		κ=	328°·10		κ=	255°·07		κ=	159°·92
M_3	R=	·028	P_1	R=	·343	μ_2	R=	·061	$(M_2K_1)_3$	R=	·018
	ζ=	295°·52		ζ=	28°·90		ζ=	335°·62		ζ=	297°·16
	H=	·027		H=	·343		H=	·058		H=	·018
	κ=	314°·74		κ=	43°·66		κ=	241°·25		κ=	63°·54

Short Period Tides—contd.

M_4	R =	·035	J_1	R =	·079	R_2	R =	...	$(2M_2K_1)_3$	R =	·009
	ζ =	218°·61		ζ =	194°·04		ζ =	...		ζ =	53°·82
	H =	·033		H =	·083		H =	...		H =	·009
	κ =	124°·23		κ =	29°·55		κ =	...		κ =	325°·88

Long Period Tides.

	R	ζ	H	κ
Lunar Monthly Tide	·061	302°·41	·057	140°·26
„ Fortnightly „	·013	211°·06	·015	253°·57
Luni-Solar „ „	·019	113°·57	·019	340°·76
Solar-Annual „	·097	258°·01	·097	333°·24
„ Semi-Annual „	·119	341°·29	·119	131°·76

VALUES OF THE TIDAL CONSTANTS, PORT ALBERT VICTOR, 1901.

The following are the amplitudes (R) and epochs (ζ) deduced from the 1901 Observations at Port Albert Victor; and also the *mean* values of the amplitudes (H) and of the epochs (κ) for each particular tide evaluated from the 1901 Observations:—

Short Period Tides.

A_0=9·748 feet.

S_1	H = R =	·099	M_6	R =	·130	Q_1	R =	·129	T_2	R =	·079
	κ = ζ =	181°·10		ζ =	184°·03		ζ =	201°·30		ζ =	37°·58
S_2	H = R =	1·104		H =	·121		H =	·144		H =	·079
	κ = ζ =	83°·62		κ =	128°·12		κ =	65°·79		κ =	38°·58
S_4	H = R =	·024	M_8	R =	·009	L_2	R =	·097	$(MS)_4$	R =	·160
	κ = ζ =	262°·31		ζ =	84°·52		ζ =	198°·21		ζ =	110°·77
S_6	H = R =	·008		H =	·008		H =	·094		H =	·156
	κ = ζ =	20°·99		κ =	129°·97		κ =	143°·85		κ =	212°·13
S_8	H = R =	·003	O_1	R =	·646	N_2	R =	·767	$(2SM)_2$	R =	·024
	κ = ζ =	313°·78		ζ =	168°·39		ζ =	328°·73		ζ =	139°·69
				H =	·723		H =	·749		H =	·023
				κ =	68°·18		κ =	34°·79		κ =	38°·33
M_1	R =	·131	K_1	R =	1·514	λ_2	R =	...	$2N_2$	R =	·164
	ζ =	258°·73		ζ =	228°·59		ζ =	...		ζ =	332°·75
	H =	·094		H =	1·620		H =	...		H =	·160
	κ =	66°·91		κ =	66°·34		κ =	...		κ =	3°·51
M_2	R =	2·906	K_2	R =	·202	ν_2	R =	·112	$(M_2N)_4$	R =	·095
	ζ =	318°·52		ζ =	217°·81		ζ =	136°·91		ζ =	249°·30
	H =	2·837		H =	·241		H =	·109		H =	·090
	κ =	59°·88		κ =	72°·57		κ =	13°·30		κ =	56°·73
M_3	R =	·030	P_1	R =	·447	μ_2	R =	·351	$(M_2K_1)_3$	R =	·067
	ζ =	189°·72		ζ =	252°·69		ζ =	138°·26		ζ =	243°·98
	H =	·029		H =	·447		H =	·334		H =	·070
	κ =	161°·77		κ =	62°·45		κ =	340°·99		κ =	183°·10
M_4	R =	·221	J_1	R =	·094	R_2	R =	...	$(2M_2K_1)_3$	R =	·040
	ζ =	334°·07		ζ =	241°·71		ζ =	...		ζ =	152°·45
	H =	·211		H =	·103		H =	...		H =	·041
	κ =	176°·79		κ =	118°·59		κ =	...		κ =	157°·42

Long Period Tides.

	R	ζ	H	κ
Lunar Monthly Tide	·038	106°·97	·035	142°·28
„ Fortnightly „	·037	246°·37	·048	8·16
Luni-Solar „ „	·093	338°·50	·091	237°·14
Solar-Annual „	·183	68°·67	·183	348°·93
„ Semi-Annual „	·154	280°·65	·154	121°·14

VALUES OF THE TIDAL CONSTANTS, BOMBAY (APOLLO BANDAR), 1901.

The following are the amplitudes (R) and epochs (ζ) deduced from the 1901 Observations at Bombay (Apollo Bandar); and also the *mean* values of the amplitudes (H) and of the epochs (κ) for each particular tide evaluated from the 1901 Observations:—

Short Period Tides.

A_0 = 10·228 feet.

S_1	H = R =	·067	M_6	R =	·005	Q_1	R =	·118	T_2	R =	·095
	κ = ζ =	180°·26		ζ =	58°·13		ζ =	176°·94		ζ =	336°·87
S_2	H = R =	1·571		H =	·005		H =	·132		H =	·095
	κ = ζ =	5°·21		κ =	2°·49		κ =	41°·56		κ =	337°·87
S_4	H = R =	·015	M_8	R =	·005	L_2	R =	·057	$(MS)_4$	R =	·122
	κ = ζ =	107°·70		ζ =	342°·03		ζ =	328°·95		ζ =	288°·09
S_6	H = R =	·004		H =	·004		H =	·056		H =	·119
	κ = ζ =	162°·41		κ =	27°·84		κ =	274°·63		κ =	29°·54
S_8	H = R =	·002	O_1	R =	·583	N_2	R =	·990	$(2SM)_2$	R =	·026
	κ = ζ =	174°·56		ζ =	149°·12		ζ =	249°·26		ζ =	205°·27
				H =	·653		H =	·966		H =	·026
				κ =	49°·00		κ =	315°·46		κ =	103°·82
M_1	R =	·099	K_1	R =	1·314	λ_2	R =	...	$2N_2$	R =	·098
	ζ =	226°·44		ζ =	207°·92		ζ =	...		ζ =	245°·84
	H =	·071		H =	1·406		H =	...		H =	·096
	κ =	34°·06		κ =	45°·67		κ =	...		κ =	276°·78
M_2	R =	4·123	K_2	R =	·296	ν_2	R =	·240	$(M_2N)_4$	R =	·055
	ζ =	230°·39		ζ =	134°·99		ζ =	47°·55		ζ =	174°·78
	H =	4·026		H =	·353		H =	·234		H =	·053
	κ =	331°·84		κ =	349°·75		κ =	284°·08		κ =	342°·43
M_3	R =	·071	P_1	R =	·405	μ_2	R =	·246	$(M_2K_1)_3$	R =	·097
	ζ =	54°·89		ζ =	232°·10		ζ =	102°·93		ζ =	210°·47
	H =	·069		H =	·405		H =	·234		H =	·102
	κ =	27°·06		κ =	41°·85		κ =	305°·84		κ =	149°·67
M_4	R =	·095	J_1	R =	·085	R_2	R =	...	$(2M_2K_1)_3$	R =	·069
	ζ =	121°·43		ζ =	202°·57		ζ =	...		ζ =	68°·93
	H =	·091		H =	·093		H =	...		H =	·070
	κ =	324°·33		κ =	79°·40		κ =	...		κ =	74°·09

Long Period Tides.

	R	ζ	H	κ
Lunar Monthly Tide	·044	34°·56	·041	69°·82
„ Fortnightly „	·037	285°·72	·048	47°·42
Luni-Solar „ „	·055	349°·30	·054	247°·85
Solar-Annual „	·171	79°·36	·171	359°·60
„ Semi-Annual „	·093	323°·34	·093	163°·83

VALUES OF THE TIDAL CONSTANTS, BOMBAY (PRINCE'S DOCK), 1901.

The following are the amplitudes (R) and epochs (ζ) deduced from the 1901 Observations at Bombay (Prince's Dock); and also the *mean* values of the amplitudes (H) and of the epochs (κ) for each particular tide evaluated from the 1901 Observations:—

Short Period Tides.

A_0=8·239 feet.

S_1	H = R =	·081	M_6	R =	·007	Q_1	R =	·120	T_2	R =	·095
	κ = ζ =	181°·21		ζ =	2[illegible]6°·77		ζ =	177°·37		ζ =	339°·42
S_2	H = R =	1·609		H =	·006		H =	·135		H =	·095
	κ = ζ =	4°·41		κ =	221°·12		κ =	41°·99		κ =	340°·42
S_4	H = R =	·022	M_8	R =	·008	L_2	R =	·071	$(MS)_4$	R =	·122
	κ = ζ =	208°·46		ζ =	30°·51		ζ =	339°·07		ζ =	289°·18
S_6	H = R =	·003		H =	·007		H =	·069		H =	·119
	κ = ζ =	174°·47		κ =	76°·32		κ =	284°·75		κ =	30°·63

Short Period Tides—contd.

S_8	H = R =	·001	O_1	R =	·579	N_2	R =	1·019	$(2SM)_2$	R =	·033
	κ = ζ =	111°·04		ζ =	148°·90		ζ =	248°·49		ζ =	·244
				H =	·648		H =	·995		H =	·032
				κ =	48°·78		κ =	314°·68		κ =	107°·98
M_1	R =	·099	K_1	R =	1·302	λ_2	R =	...	$2N_2$	R =	·099
	ζ =	221°·25		ζ =	207°·07		ζ =	...		ζ =	247°·06
	H =	·071		H =	1·393		H =	...		H =	·097
	κ =	29°·47		κ =	44°·82		κ =	...		κ =	278°·00
M_2	R =	4·173	K_2	R =	·297	ν_2	R =	·241	$(M_2N)_4$	R =	·076
	ζ =	229°·01		ζ =	133°·73		ζ =	46°·53		ζ =	188°·35
	H =	4·074		H =	·354		H =	·235		H =	·072
	κ =	330°·47		κ =	348°·49		κ =	283°·06		κ =	356°·00
M_3	R =	·075	P_1	R =	·398	μ_2	R =	·243	$(M_2K_1)_3$	R =	·102
	ζ =	52°·60		ζ =	231°·99		ζ =	105°·09		ζ =	208°·64
	H =	·072		H =	·398		H =	·231		H =	·106
	κ =	24°·77		κ =	41°·74		κ =	308°·60		κ =	147°·84
M_4	R =	·091	J_1	R =	·028	R_2	R =	...	$(2M_2K_1)_3$	R =	·078
	ζ =	130°·02		ζ =	203°·68		ζ =	...		ζ =	63°·50
	H =	·087		H =	·007		H =	...		H =	·079
	κ =	332°·93		κ =	80°·51		κ =	...		κ =	68°·66

Long Period Tides.

	R	ζ	H	κ
Lunar Monthly Tide . . .	·048	24°·32	·044	59°·58
„ Fortnightly „ . . .	·045	276°·29	·058	37°·98
Luni-Solar „ „ . . .	·035	342°·94	·034	241°·49
Solar-Annual „ . . .	·157	80°·59	·157	0°·83
„ Semi-Annual „ . . .	·101	320°·00	·101	166°·49

VALUES OF THE TIDAL CONSTANTS, MADRAS, 1901.

The following are the amplitudes (R) and epochs (ζ) deduced from the 1901 Observations at Madras; and also the *mean* values of the amplitudes (H) and of the epochs (κ) for each particular tide evaluated from the 1901 Observations:—

Short Period Tides.

A_0=2·282 feet.

S_1	H = R =	·035	M_6	R =	·002	Q_1	R =	·005	T_2	R =	·027
	κ = ζ =	76°·91		ζ =	182°·86		ζ =	76°·55		ζ =	204°·71
S_2	H = R =	·456		H =	·002		H =	·005		H =	·027
	κ = ζ =	271°·54		κ =	128°·73		κ =	301°·97		κ =	205°·74
S_4	H = R =	·001	M_8	R =	·002	L_2	R =	·048	$(MS)_4$	R =	·007
	κ = ζ =	48°·37		ζ =	232°·43		ζ =	313°·30		ζ =	155°·04
S_6	H = R =	·001		H =	·002		H =	·047		H =	·007
	κ = ζ =	94°·76		κ =	280°·26		κ =	259°·21		κ =	256°·99
S_8	H = R =	·001	O_1	R =	·086	N_2	R =	·235	$(2SM)_2$	R =	·015
	κ = ζ =	66°·80		ζ =	61°·17		ζ =	167°·83		ζ =	315°·00
				H =	·096		H =	·229		H =	·014
				κ =	321°·57		κ =	234°·81		κ =	213°·04
M_1	R =	·011	K_1	R =	·275	λ_2	R =	...	$2N_2$	R =	·039
	ζ =	66°·25		ζ =	139°·83		ζ =	...		ζ =	166°·90
	H =	·008		H =	·294		H =	...		H =	·038
	κ =	234°·73		κ =	337°·56		κ =	...		κ =	198°·88
M_2	R =	1·109	K_2	R =	·104	ν_2	R =	·069	$(M_2N)_4$	R =	·046
	ζ =	140°·03		ζ =	52°·06		ζ =	331°·81		ζ =	70°·63
	H =	1·083		H =	·124		H =	·067		H =	·044
	κ =	241°·98		κ =	266°·78		κ =	209°·08		κ =	239°·55
M_3	R =	·003	P_1	R =	·094	μ_2	R =	·036	$(M_2K_1)_3$	R =	·011
	ζ =	56°·31		ζ =	167°·37		ζ =	347°·96		ζ =	102°·24
	H =	·003		H =	·094		H =	·034		H =	·012
	κ =	29°·24		κ =	337°·15		κ =	191°·87		κ =	41°·93

Short Period Tides—contd.

M_4	R =	·007	J_1	R =	·011	R_2	R =	...	$(2M_2K_1)_3$	R =	·002
	ζ =	359°·69		ζ =	129°·33		ζ =	...		ζ =	276°·71
	H =	·006		H =	·012		H =	...		H =	·002
	κ =	203°·00		κ =	5°·86		κ =	...		κ =	282°·89

Long Period Tides.

	R	ζ	H	κ
Lunar Monthly Tide	·028	218°·27	·026	253°·25
„ Fortnightly „	·018	299°·02	·023	60°·17
Luni-Solar „ „	·018	124°·06	·018	22°·11
Solar-Annual „	·423	287°·11	·423	207°·33
„ Semi-Annual „	·242	272°·84	·242	113°·28

VALUES OF THE TIDAL CONSTANTS, KIDDERPORE, 1901.

The following are the amplitudes (R) and epochs (ζ) deduced from the 1901 Observations at Kidderpore; and also the *mean* values of the amplitudes (H) and of the epochs (κ) for each particular tide evaluated from the 1901 Observations:—

Short Period Tides.

A_0 = 10·358 feet.

S_1	H = R =	·084	M_6	R =	·188	Q_1	R =	·021	T_2	R =	·057
	κ = ζ =	192°·60		ζ =	16°·98		ζ =	106°·70		ζ =	135°·72
S_2	H = R =	1·581		H =	·175		H =	·024		H =	·057
	κ = ζ =	99°·12		κ =	324°·47		κ =	332°·98		κ =	136°·77
S_4	H = R =	·110	M_8	R =	·082	L_2	R =	·241	$(MS)_4$	R =	·755
	κ = ζ =	109°·11		ζ =	224°·40		ζ =	108°·31		ζ =	334°·43
S_6	H = R =	·010		H =	·075		H =	·234		H =	·737
	κ = ζ =	30°·67		κ =	274°·40		κ =	54°·48		κ =	76°·93
S_8	H = R =	·002	O_1	R =	·183	N_2	R =	·741	$(2SM)_2$	R =	·071
	κ = ζ =	336°·37		ζ =	[illegible]15°·85		ζ =	338°·84		ζ =	120°·74
				H =	·205		H =	·724		H =	·069
				κ =	16°·82		κ =	46°·64		κ =	18°·24
M_1	R =	·029	K_1	R =	·380	λ_2	R =	...	$2N_2$	R =	·123
	ζ =	42°·59		ζ =	216°·12		ζ =	...		ζ =	286°·00
	H =	·021		H =	·407		H =	...		H =	·120
	κ =	211°·33		κ =	53°·83		κ =	...		κ =	319°·12
M_2	R =	3·940	K_2	R =	·355	ν_2	R =	·348	$(M_2N)_4$	R =	·136
	ζ =	314°·51		ζ =	237°·31		ζ =	132°·38		ζ =	258°·34
	H =	3·847		H =	·424		H =	·339		H =	·129
	κ =	57°·00		κ =	91°·99		κ =	10°·44		κ =	68°·65
M_3	R =	·042	P_1	R =	·145	μ_2	R =	·238	$(M_2K_1)_3$	R =	·089
	ζ =	19°·28		ζ =	234°·64		ζ =	335°·28		ζ =	90°·86
	H =	·041		H =	·145		H =	·227		H =	·093
	κ =	353°·02		κ =	44°·44		κ =	180°·28		κ =	31°·07
M_4	R =	·840	J_1	R =	·012	R_2	R =	...	$(2M_2K_1)_3$	R =	·039
	ζ =	189°·99		ζ =	253°·30		ζ =	...		ζ =	315°·32
	H =	·800		H =	·013		H =	...		H =	·039
	κ =	34°·99		κ =	129°·52		κ =	...		κ =	322°·61

Long Period Tides.

	R	ζ	H	κ
Lunar Monthly Tide	·290	351°·46	·268	26°·15
„ Fortnightly „	·194	281°·15	·249	41°·71
Luni-Solar „ „	·879	143°·08	·858	40°·59
Solar-Annual „	2·387	234°·32	2·387	154°·52
„ Semi-Annual „	·863	136°·88	·863	337°·28

Values of the Tidal Constants, Rangoon, 1901.

The following are the amplitudes (R) and epochs (ζ) deduced from the 1901 Observations at Rangoon; and also the *mean* values of the amplitudes (H) and of the epochs (κ) for each particular tide evaluated from the 1901 Observations:—

Short Period Tides.

A_0=10·253 feet.

S_1	H = R =	·122	M_6	R =	·282	Q_1	R =	·013	T_2	R =	·149
	κ = ζ =	129°·81		ζ =	127°·82		ζ =	129°·26		ζ =	127°·25
S	H = R =	2·151		H =	·263		H =	·015		H =	·149
	κ = ζ =	167°·10		κ =	76°·91		κ =	356°·37		κ =	128°·32
S_4	H = R =	·072	M_8	R =	·107	L_2	R =	·511	$(MS)_4$	R =	·399
	κ = ζ =	258°·35		ζ =	38°·74		ζ =	183°·23		ζ =	102°·16
S_6	H = R =	·012		H =	·097		H =	·495		H =	·389
	κ = ζ =	55°·24		κ =	90°·86		κ =	129°·64		κ =	205°·19
S_8	H = R =	·003	O_1	R =	·273	N_2	R =	1·089	$(2SM)_2$	R =	·167
	κ = ζ =	120°·58		ζ =	122°·39		ζ =	49°·53		ζ =	150°·81
				H =	·306		H =	1·063		H =	·163
				κ =	23°·91		κ =	118°·15		κ =	47°·78
M_1	R =	·018	K_1	R =	·626	λ_2	R =	...	$2N_2$	R =	·223
	ζ =	217°·33		ζ =	196°·50		ζ =	..		ζ =	348°·34
	H =	·013		H =	·670		H =	...		H =	·217
	κ =	26°·34		κ =	34°·19		κ =	...		κ =	22°·56
M_2	R =	6·129	K_2	R =	·463	ν_2	R =	·435	$(M_2N)_4$	R =	·094
	ζ =	25°·35		ζ =	308°·03		ζ =	215°·25		ζ =	326°·54
	H =	5·984		H =	·553		H =	·425		H =	·090
	κ =	128°·38		κ =	162°·66		κ =	94°·08		κ =	138°·19
M_3	R =	·031	P_1	R =	·148	μ_2	R =	·518	$(M_2K_1)_3$	R =	·095
	ζ =	130°·79		ζ =	238°·51		ζ =	80°·13		ζ =	119°·65
	H =	·030		H =	·148		H =	·494		H =	·100
	κ =	105°·33		κ =	48°·33		κ =	286°·19		κ =	60°·37
M_4	R =	·428	J_1	R =	·047	R_2	R =	...	$(2M_2K_1)_3$	R =	·116
	ζ =	318°·69		ζ =	256°·62		ζ =	...		ζ =	41°·75
	H =	·408		H =	·051		H =	...		H =	·119
	κ =	164°·75		κ =	132°·54		κ =	...		κ =	50°·12

Long Period Tides.

	R	ζ	H	κ
Lunar Monthly Tide	·256	339°·60	·236	14°·00
„ Fortnightly „	·066	302°·98	085	62°·97
Luni-Solar „ „	·474	151°·82	·463	48°·79
Solar-Annual „	1·249	228°·39	1·249	148°·57
„ Semi-Annual „	·083	176°·12	·083	16°·48

Values of the Tidal Constants, Port Blair, 1901.

The following are the amplitudes (R) and epochs (ζ) deduced from the 1901 Observations at Port Blair; and also the *mean* values of the amplitudes (H) and of the epochs (κ) for each particular tide evaluated from the 1901 Observations:—

Short Period Tides.

A_0=4·784 feet.

S_1	H = R =	·018	M_6	R =	·001	Q_1	R =	·018	T_2	R =	·038
	κ = ζ =	77°·78		ζ =	74°·75		ζ =	29°·59		ζ =	279°·56
S_2	H = R =	·958		H =	·001		H =	·020		H =	·038
	κ = ζ =	316°·60		κ =	23°·14		κ =	256°·33		κ =	280°·62

Short Period Tides—contd.

S_4	H = R =	·010	M_8	R =	·002	L_2	R =	·090	$(MS)_4$	R =	·028
	κ = ζ =	188°·30		ζ =	121°·61		ζ =	321°·86		ζ =	67·63
S_6	H = R =	·003		H =	·002		H =	·088		H =	·027
	κ = ζ =	174°·47		κ =	172°·80		κ =	268°·17		κ =	170·43
S_8	H = R =	·001	O_1	R =	·142	N_2	R =	·389	$(2SM)_2$	R =	·031
	κ = ζ =	243°·44		ζ =	40°·24		ζ =	207°·70		ζ =	227°·13
				H =	·159		H =	·380		H =	·030
				κ =	301°·52		κ =	275°·96		κ =	124°·33
M_1	R =	·029	K_1	R =	·374	λ_2	R =	...	$2N_2$	R =	·034
	ζ =	87°·79		ζ =	129°·98		ζ =	...		ζ =	229°·84
	H =	·021		H =	·400		H =	...		H =	·033
	κ =	256°·68		κ =	327°·67		κ =	...		κ =	263°·58
M_2	R =	2·030	K_2	R =	·213	ν_2	R =	·100	$(M_2N)_4$	R =	·047
	ζ =	177°·39		ζ =	91°·72		ζ =	3°·30		ζ =	101°·29
	H =	1·982		H =	·254		H =	·098		H =	·045
	κ =	280°·18		κ =	306°·37		κ =	241°·80		κ =	272°·35
M_3	R =	·006	P_1	R =	·134	μ_2	R =	·096	$(M_2K_1)_3$	R =	·014
	ζ =	50°·06		ζ =	154°·42		ζ =	93°·91		ζ =	156°·00
	H =	·006		H =	·134		H =	·092		H =	·015
	κ =	24°·26		κ =	324°·23		κ =	299°·51		κ =	96°·49
M_4	R =	·024	J_1	R =	·020	R_2	R =	...	$(2M_2K_1)_3$	R =	·006
	ζ =	271°·48		ζ =	118°·38		ζ =	...		ζ =	177°·04
	H =	·023		H =	·022		H =	...		H =	·006
	κ =	117°·07		κ =	354°·43		κ =	...		κ =	184°·94

Long Period Tides.

	R	ζ	H	κ
Lunar Monthly Tide	·033	335°·00	·030	9°·53
„ Fortnightly „	·021	299°·33	·027	59°·56
Luni-Solar „ „	·029	187°·74	·028	84°·94
Solar-Annual „	·245	240°·35	·245	160°·54
„ Semi-Annual „	·047	319°·41	·047	159°·79

42. The usual work in connection with the preparation of the tide-tables for 1903 has been done. The tables contain predictions of high and low-water times and heights for 39 ports.

47. The usual tabular statements Nos. 1 to 5 are appended, showing the percentage and the amount of errors in the predicted times and heights of high and low-water for the year 1901 at 17 stations, as determined by comparison of the predictions given in the tide-tables with actual values measured from the tidal diagrams at 13 stations; and from tide-poles at 4 stations; the former being made by assistants in this office, and the latter by Port Officer's subordinates.

No. 1.

Statement showing the percentage and the amount of the errors in the Predicted Times of High Water at the various Tidal Stations for the year 1901.

Stations.	Automatic or Tide-pole observations.	Number of comparisons between actual and predicted values.	Errors of 5 minutes and under.	Errors over 5 minutes and under 15 minutes.	Errors over 15 minutes and under 20 minutes.	Errors over 20 minutes and under 30 minutes.	Errors over 30 minutes.
			Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Suez	Au.	704	31	40	11	12	6
Perim	Au.	678	23	33	12	18	14
Aden	Au.	676	38	42	10	8	2
Bushire	Au.	123*	25	37	10	15	8
Karachi	Au.	703	32	49	9	6	4
Porbandar	Au.	382†	17	34	17	21	11
Port Albert Victor	Au.	701	31	37	10	11	11
Bhávnagar	T. P.	212	15	77	5	2	1
Bombay { Apollo Bandar	Au.	697	34	44	10	8	4
Bombay { Prince's Dock	Au.	705	41	42	7	6	4
Madras	Au.	697	29	40	13	12	6
Kidderpore	Au.	704	23	36	14	18	9
Chittagong	T. P.	364	35	48	5	5	7
Akyab	T. P.	365	96	4	...	...	...
Rangoon	Au.	705	28	39	13	16	4
Moulmein	T. P.	332	64	28	5	2	1
Port Blair	Au.	704	36	45	11	6	2

* Including 6 comparisons which gave no definite results owing to the peculiarity of the tide-curve being such as to show no definite High Water.

† From observations taken from 1st January to 14th June 1901, and from 22nd November to 31st December 1901.

No. 2.

Statement showing the percentage and the amount of the errors in the Predicted Times of Low Water at the various Tidal Stations for the year 1901.

Stations.	Automatic or Tide-pole observations.	Number of comparisons between actual and predicted values.	Errors of 5 minutes and under.	Errors over 5 minutes and under 15 minutes.	Errors over 15 minutes and under 20 minutes.	Errors over 20 minutes and under 30 minutes.	Errors over 30 minutes.
			Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Suez	Au.	701	19	35	15	19	12
Perim	Au.	678	20	33	13	18	16
Aden	Au.	679	31	48	10	8	3
Bushire	Au.	123*	4	6	10	19	51
Karachi	Au.	706	32	44	14	8	2
Porbandar	Au.	388†	36	41	9	10	4
Port Albert Victor	Au.	698	22	32	10	17	19
Bhávnagar	T. P.	213	12	69	6	8	5
Bombay { Apollo Bandar	Au.	699	17	36	19	20	8
Bombay { Prince's Dock	Au.	706	27	42	15	12	4
Madras	Au.	697	18	30	18	21	13
Kidderpore	Au.	703	27	40	14	13	6
Chittagong	T. P.	365	34	47	6	6	7
Akyab	T. P.	365	49	51	...	...	...
Rangoon	Au.	704	26	36	12	19	7
Moulmein	T. P.	339	42	37	7	9	5
Port Blair	Au.	705	33	52	8	5	2

* Including 12 comparisons which gave no definite results owing to the peculiarity of the tide-curve being such as to show no definite Low Water.

† From observations taken from 1st January to 14th June 1901, and from 22nd November to 31st December 1901.

No. 3.

Statement showing the percentage and the amount of the errors in the Predicted Heights of High Water at the various Tidal Stations for the year 1901.

Stations.	Automatic or Tide-pole observations.	Number of comparisons between actual and predicted values.	Mean range at springs in feet.	Errors of 4 inches and under.	Errors over 4 inches and under 8 inches.	Errors over 8 inches and under 12 inches.	Errors over 12 inches.
				Per cent.	Per cent.	Per cent.	Per cent.
Suez	Au.	704	5·5	65	28	6	1
Perim	Au.	678	5·6	89	11	...	...
Aden	Au.	670	6·7	99	1	...	...
Bushire	Au.	123*	4·8	57	21	8	9
Karachi	Au.	703	9·3	79	19	1	1
Porbandar	Au.	382†	7·3	48	32	16	4
Port Albert Victor	Au.	701	11·9	45	35	18	2
Bhávnagar	T. P.	212	31·4	42	31	17	10
Bombay { Apollo Bandar	Au.	697	13·9	70	26	3	1
Bombay { Prince's Dock	Au.	705	13·9	69	26	4	1
Madras	Au.	697	3·5	79	20	1	...
Kidderpore	Au.	704	11·7	36	22	16	26
Chittagong	T. P.	364	13·3	74	15	7	4
Akyab	T. P.	365	8·3	85	14	1	...
Rangoon	Au.	705	16·4	50	32	14	4
Moulmein	T. P.	332	12·7	37	23	15	25
Port Blair	Au.	704	6·6	97	3	...	...

* Including 6 comparisons which gave no definite results owing to the peculiarity of the tide-curve being such as to show no definite High Water.
† From observations taken from 1st January to 14th June 1901, and from 22nd November to 31st December 1901.

No. 4.

Statement showing the percentage and the amount of the errors in the Predicted Heights of Low Water at the various Tidal Stations for the year 1901.

Stations.	Automatic or Tide-pole observations.	Number of comparisons between actual and predicted values.	Mean range at springs in feet.	Errors of 4 inches and under.	Errors over 4 inches and under 8 inches.	Errors over 8 inches and under 12 inches.	Errors over 12 inches.
				Per cent.	Per cent.	Per cent.	Per cent.
Suez	Au.	701	5·5	64	26	9	1
Perim	Au.	678	5·6	94	6	...	...
Aden	Au.	679	6·7	98	2	...	...
Bushire	Au.	123*	4·8	57	20	7	6
Karachi	Au.	706	9·3	80	17	2	1
Porbandar	Au.	388†	7·3	38	26	16	20
Port Albert Victor	Au.	698	11·9	56	29	12	3
Bhávnagar	T. P.	213	31·4	44	25	16	15
Bombay { Apollo Bandar	Au.	699	13·9	69	26	4	1
Bombay { Prince's Dock	Au.	706	13·9	68	24	7	1
Madras	Au.	697	3·5	79	21	...	...
Kidderpore	Au.	703	11·7	35	27	17	21
Chittagong	T. P.	365	13·3	65	19	8	8
Akyab	T. P.	365	8·3	81	17	1	1
Rangoon	Au.	704	16·4	27	29	22	22
Moulmein	T. P.	339	12·7	33	25	20	22
Port Blair	Au.	705	6·6	96	4	...	...

* Including 12 comparisons which gave no definite results owing to the peculiarity of the tide-curve being such as to show no definite Low Water.
† From observations taken from 1st January to 14th June 1901, and from 22nd November to 31st December 1901.

No. 5.

Table of Average Errors in the Predicted Times and Heights of High and Low Water at the several Tidal Stations for the year 1901.

Stations.	Automatic or Tide-pole observations.	Mean range at springs in feet.	Average Errors: Of Time in Minutes. H. W.	L. W.	Of Height in terms of the range. H. W.	L. W.	Of Height in inches. H. W.	L. W.
Open Coast.								
Suez	Au.	5·5	12	16	·061	·061	4	4
Perim	Au.	5·6	17	18	·030	·030	2	2
Aden	Au.	6·7	10	10	·012	·025	1	2
Bushire	Au.	4·8	14	38	·087	·c87	5	5
Karachi	Au.	9·3	11	11	·027	·027	3	3
Porbandar	Au.	7·3	17	11	·057	·080	5	7
Port Albert Victor	Au.	11·9	15	20	·035	·035	5	5
Bhávnagar	T. P.	31·4	9	12	·019	·019	7	7
Bombay { Apollo Bandar	Au.	13·9	10	16	·018	·024	3	4
Bombay { Prince's Dock	Au.	13 9	9	12	·024	·024	4	4
Madras	Au.	3 5	12	17	·071	·071	3	3
Akyab	T. P.	8·3	2	5	·020	·030	2	3
Port Blair	Au.	6·6	10	9	·025	·025	2	2
General Mean			11	15	·037	·041	...	...
Riverain.								
Kidderpore	Au.	11 7	15	13	·064	·057	9	8
Chittagong	T. P.	13·3	11	11	·025	·031	4	5
Rangoon	Au.	16·4	12	14	·025	·041	5	8
Moulmein	T. P.	12·7	5	10	·059	·052	9	8
General Mean			11	12	·043	·045	...	...

The foregoing statement for the year 1901 may be thus summarised :—

Percentage of time predictions within 15 minutes of actuals.

		High-Water. Per cent.	Low-Water. Per cent.
Open coast Stations {	11 at which predictions were tested by S. R. Tide-gauge	71	60
	2 " " Tide-pole	96	91
Riverain Stations {	2 " " S. R. Tide-gauge	63	65
	2 " " Tide-pole	88	80

Percentage of height predictions within 8-inches of actuals.

		High-Water. Per cent.	Low-Water. Per cent.
Open coast Stations {	11 at which predictions were tested by S. R. Tide-gauge	93	91
	2 " " Tide-pole	86	84
Riverain Stations {	2 " " S. R. Tide-gauge	70	59
	2 " " Tide-pole	75	71

Percentage of height predictions within one-tenth of mean range at springs.

		High-Water. Per cent.	Low-Water. Per cent.
Open coast Stations	11 at which predictions were tested by S. R. Tide-gauge	93	91
	2 " " Tide-pole	99	99
Riverain Stations	2 " " S. R. Tide-gauge	90	92
	2 " " Tide-pole	91	91

48. In the above summary the tests are of two classes, the first and more accurate class being that made by means of self-registering tide-gauges, and the second by means of tide-poles. Height measurements, except in rough weather, can be accurately taken from a tide-pole, but for the corresponding time readings, owing to the chance of inaccuracy of the time locally kept, a considerable margin for errors must be allowed.

The predictions for the year 1901 at the riverain stations were better at Kidderpore and Rangoon; while at Chittagong they were about the same as they were last year; and at Moulmein they were again somewhat inferior.

At Kidderpore the greatest difference between the actual and predicted heights of low-water was 2 feet 5 inches in August and in October 1901; the actual height was less in August, and in excess in October. The greatest difference in high-water was 5 feet 8 inches, in November, the actual height being in excess.

At Rangoon the predictions were again this year in excess of the actuals: the greatest error in low-water heights was 1 foot 11 inches, which occurred in June and again in September 1901.

At Moulmein the greatest error in the low-water heights was 2 feet 4 inches in October 1901. The greatest error in high-water heights was 3 feet 4 inches; and occurred in the same month. In both instances, the actuals were in excess of the predictions.

Bench-Marks.

50. The bench-marks of reference at the tidal stations still working, were found undisturbed and in good order.

Levelling Operations.

51. The levelling detachment was again employed for a time on the Eastern Bengal State Railway, from Parbatipur to Dhubri; and for the remaining portion of the field season in Bengal, from Siliguri to Sonákhoda Base-Line; and in Assam, from Fakirganj to Gauháti.

The villagers were very friendly throughout the season.

The out-turn of work amounted to 259 miles of double-levelling on the main lines, and 6 miles on the branch-lines. The total rises and falls aggregated 4,080 feet; and the two levels were set up at 3,255 stations. The heights of 7 old and 33 new embedded bench-marks, 101 inscribed bench-marks, 4 Great Trigonometrical Survey Stations, and 14 Railway bench-marks were determined.

53. The usual tabular statements of the levelling operations are appended:—

Table A, giving the Great Trigonometrical stations connected and the errors in their original heights.

Table B, giving the comparisons of the levelling staves with a 10-foot portable standard bar.

TABLE A.

List of Great Trigonometrical Survey Stations Connected by Spirit-levelling. Season 1901-02.

Name of Station.	Height in feet above mean Sea-level. By spirit Levelling.	Height in feet above mean Sea-level. By triangulation.	Error of height by triangulation in feet.	Remarks.
Rámganj T. S. of the N. E. Longitudinal Series	231	231*	0	* Final value. Heights refer to lower marks.
Sonákhoda T. S. of the N. E. Longitudinal Series.	208	208*	0	
Dhubri H. S. of the Assam Longitudinal Series.	141	139	−2	
Goálpára h. s. of the Assam Longitudinal Series.	...	387	...	The levelling emanates from Goálpára h. s., the trigonometrical height being provisionally accepted as correct.

TABLE B.

Results of Comparison of Staves. Season 1901-02.

Place and date of Comparison.	Difference of length of Staff from 10 feet. Staff No. B1.	Staff No. B2.	Staff No. 13.	Staff No. 4.
Siliguri, 30th October 1901	+0·0038110	+0·0012125	+0·0029468	+0·0021580
Islampur, 19th November 1901	+0·0036266	+0·0007532	+0·0019117	+0·0017451
Dhubri, 2nd February 1902	+0·0038290	+0·0006628	+0·0013409	+0·0016281
Dhubri, 1st May 1902	+0·0042306	+0·0016149	+0·0034847	+0·0026999

H. L. CROSTHWAIT, CAPTAIN, R.E.
E. J. CONNOR.

V

TOPOGRAPHY IN UPPER BURMA.

Extract from the Narrative Report of P. J. Doran, Esq., in charge Nos. 11 and 21 Parties, Season 1901-02.

6. Remarks on the country under Survey, etc.

The detail survey on the 1-inch scale during the year under report was carried on almost entirely in the Southern Shan States. It embraced portions of the States of Mawkmai, Möng Nai, Lai Hka, Möng Pan, Möng Nawng, Kĕng Hkam, Kĕng Tung, and West Manglön. There was but a small area surveyed in West Manglön (Northern Shan States) up to the Salween River, the gap left undone during the previous season.

Some of the country planetabled this season was perhaps the worst we have yet met with.

Sheet No. 440. Lat. $\frac{21^\circ\text{-}0'}{21^\circ\text{-}15'}$; Long $\frac{98^\circ\text{-}0'}{98^\circ\text{-}30'}$. The western half is a plateau 3,000 feet above sea-level. This area is for the most part void of tree jungle and fairly well cultivated, yet for the surveyor the difficulties presented by the elephant grass during the winter months were almost insurmountable.

In the eastern half of the sheet on the contrary there was very little plain ground and the hills were high and difficult to move about in and were covered with heavy jungle.

One peculiar feature of this sheet is, that the water constantly sinks into the ground though there are innumerable springs in the higher hills, the valleys, except for the larger streams which course through the country, are waterless.

This sheet is fairly well populated, the average being one village to about 2 square miles.

The villages on the western half of this sheet are well scattered, but in the eastern half they cluster in an area of about 60 square miles at the south-east corner leaving the bulk of the ground almost depopulated, thus blocks of 50 to 60 square miles having no villages at all.

Sheet No. 441. Lat. $\frac{20^\circ\text{-}45'}{21^\circ\text{-}0'}$; Long. $\frac{98^\circ\text{-}0'}{98^\circ\text{-}15'}$. This sheet consists of a narrow strip of plateau ground to the west which rises somewhat abruptly into broken ranges of hills, difficult of access throwing off to the east, rugged and steep spurs towards the Nam Tĕng River. The rest of the ground beyond the valley of the Nam Tĕng is for the most part hilly, and the entire sheet covered with heavy jungle. The higher hills with tree jungle only whereas the lower ground has elephant grass and brush wood.

In this sheet there is an average of one village to 2½ square miles, and these are fairly scattered except for an area of about 30 square miles near and about Kĕng Tung, which contains several villages, some large, and closely grouped together. A tract of about 180 square miles is running north and south through the middle of the sheet, where there are only a few small villages not worthy of notice.

Sheet No. 442. Lat. $\frac{20^\circ\text{-}30'}{20^\circ\text{-}45'}$; Long. $\frac{98^\circ\text{-}0'}{98^\circ\text{-}30'}$. This sheet is almost entirely hilly and jungle clad, high tree jungle with little undergrowth covering the tops of the hills, whereas low brush jungle and bamboo thickly cover the valleys and streams.

The hills are to a great extent high and rocky and to the west a feature of note and interest is the group of high rocky hills inaccessible to man, and portions of the narrow valley formed by them being one succession of steep deep hollows surrounded and separated from each other by sharp-pointed rocks. This sheet has its villages well distributed though it is the least populated having only one village to 5 square miles.

Sheet No. 443. Lat. $\frac{20^\circ\text{-}15'}{20^\circ\text{-}30'}$; Long. $\frac{98^\circ\text{-}0'}{98^\circ\text{-}30'}$. This sheet is a mass of high hills with very little plain ground. The level ground, however, wherever it occurs is

well peopled and well cultivated. Except for the cultivated part, the country is a mass of dense jungle, the higher hills hard of access. The features are bold and stand out well. The average is one village to every 3 square miles, the villages are well planted.

Sheets Nos. 510 to 512. Lat. $\frac{20°\text{-}15'}{21°\text{-}0'}$, Long. $\frac{98°\text{-}30'}{99°\text{-}0'}$. The area surveyed on the sheets was only as much as fell to the west of the Salween River.

In the above sheets the hills are heavy, difficult of access, densely covered with jungle and wild. There are few villages as will be seen from the small average being one village to every 10 square miles, but they are well distributed over the area, and the only roads worth mentioning which pass through these sheets are the high roads or trade routes going east and which tap the whole country. The Salween, up to which the work was carried, flows through a deep precipitous narrow valley falling in a distance of 60 miles only 200 feet.

P. J. DORAN.

VI

TOPOGRAPHY IN SIND.

Extract from the Narrative Report of C. F. Erskine, Esq., in charge No. 12 Party (Sind), Season 1901-02.

GENERAL PLAN OF SURVEY OPERATIONS.

3. During the year under report detail survey operations were carried on in the Shikárpur, Lárkhána and Hyderabad districts and also in the Khairpur State. Triangulation and traversing in advance were also carried on in the same districts in continuation of the previous season's work.

Detail survey was carried out entirely by interpolation, with the exception of a strip on either bank of the Nára River, where, owing to the density of the Bábul jungle, the chain had to be freely used. The total number of fixings from which the work was checked by the Camp Officers is 1,479.

The total area topographically surveyed on the 2-inch scale is 1,597 square miles, and on the ½-inch scale 4,556 square miles.

COMPOSITION OF DETACHMENTS EMPLOYED.

4. At the commencement of the field season the composition of the detachments employed on the various survey operations was as follows :—

Detail Survey, 2-inch Scale.

Mr. Warwick's camp consisting of nine men averaged per man per mensem 24·52 square miles and 454·3 fixings.

Mr. Bond's camp consisting of eight men averaged per man per mensem 14·65 square miles and 390 fixings; this camp which was working in the Nára Valley had to deal with very difficult ground, and the chain had to be constantly used.

Late in the season a small camp was formed and placed under Mr. Berrill, the average out-turn per man for the month being 24 square miles and 459 fixings.

Detail Survey, ¼-inch Scale.

Munshi Rahmatullah's camp consisting of five men averaged out-turn per man per mensem 195 square miles and 215 fixings. This was the first season that this party had been employed on ¼-inch work, and owing to the scarcity of water the surveyors were frequently compelled to camp at some distance from their work.

Triangulation and Traversing.

5. In the Traverse Camp under Mr. Vander-Beek the average out-turn of chaining per man per mensem was 57⅗ linear miles.

Mr. H. A. Charrier and Mr. Berrill were employed in running a net-work of triangulation in continuation of the previous season's work.

Two net-works of triangulation were run to afford reliable points to the detail surveyors working in the desert portions of the Shikárpur district and of the Khairpur State west of the Nára River.

(*a*) A net-work over the desert portion of the Khairpur State, situated on the west of the Nárá River, was carried in well-planned triangles with an average of 10-mile sides. The stations of this net-work were marked by platforms of brick and clay; two bricks marked with a dot and circle were also embedded, one flush with the upper surface of the platform and the other buried about 2 feet below the surface. An 8-inch theodolite was used.

(*b*) A second net-work was carried over the desert portion of the Shikárpur district, situated between the northern boundary of the Khairpur State and the cultivated area south of the River Indus. The stations of this net-work were marked in the same manner as those described in (*a*). A 7-inch theodolite was employed.

Traversing by theodolite was carried on in continuation of last season's work and consisted of main circuits, sub-circuits, connections with triangulated points, and a village boundary survey, offsets to the angles of the boundaries being measured and recorded in the field books.

During the past season 7½ main circuits and 9 sub-circuits were measured, and the boundary traverse survey of 334 villages in British territory was completed: in addition to this 32 connecting lines were run in the Khairpur State where the village boundaries are undemarcated. The total area traversed is 1,763 square miles, which, together with the area traversed in former seasons and not yet topographically surveyed, makes an area of about 4,509 square miles available for detail survey during the coming field season. The total number of stations observed at is 7,402 and the angular work was checked by observations for azimuth taken at 60 stations on main and sub-circuits. The total linear measurements amounted to 2,125 miles, and were checked by 17 connections with the stations of the minor triangulation executed by this party and with some stations of the Sehwan Secondary Series.

The average correction per 1,000 links is 0·4 link, and the angular error per station 0′ 34″.

No permanent marks were erected at traverse stations, but wherever possible the stones embedded by the Revenue authorities to demarcate village boundaries were utilized.

In addition to the village boundary survey 34 bench marks, laid down by the Railway authorities on the Kotri-Rohri Branch of the North-Western Railway, were connected with the traversing, involving observations at 36 stations and also 20¾ miles of chain measurements.

6. The country topographically surveyed on the 2-inch scale during the year under report was generally of the monotonous description dealt with in former seasons; near the River Indus the country is well populated and highly cultivated; as one moves eastward the population becomes noticeably scantier, and large tracts of uncultivated ground interspersed with sand hills are met with; the north-eastern portion is very hilly, the hills, rising to a height of 300 feet above the surrounding ground level, are perfectly bare and destitute of water.

Of the small strip on either bank of the Nára River, surveyed on the 2-inch scale, the portion situated in the Khairpur State is uncultivated, being thick marshy jungle and sand hills, intersected with streams locally known as "Sángs" and these are infested with crocodiles. The population is very scanty, and until lately the whole valley was merely a shooting preserve for the ruler of the State. The northern portion of the strip surveyed lies within British territory and is better populated and cultivated, but even here all the land to the east of the Nára River is practically desert, as an unbroken stretch of waterless sand hills runs from the river to the Bikaner desert. The ¼-inch work comprises the whole of the desert situated within the limits of the Khairpur State, no cultivation was met with, the villages were of the most primitive description, and the population barely averaged one per square mile. The inhabitants of this portion of the State are mostly herdsmen who move their herds of camels, cattle, sheep and goats from one place to another as soon as the water and pasturage in the vicinity of their encampment becomes exhausted.

C. F. ERSKINE.

VII

TOPOGRAPHY IN THE PUNJAB.

Extract from the Narrative Report of Major W. J. Bythell, R.E., in charge No. 18 Party, Season 1901-02.

III. General plan of Survey Operations giving scope of work allotted to party and actual methods of Survey employed.

The party was divided into the following detachments for the field season :—

Mr. Robert with 3 Sub-Surveyors, 2 Draftsmen and two Apprentices, remained at recess quarters during the field season to continue the compilation of the 2″ field sections of Lahore district and ensure the supply thereof to the Sub-Surveyors in the field. In this class of work the heaviest item is the plotting, projection and compilation of these field sheets, and practically a certain number of hands might be continuously employed on this throughout the year as the field-work (though the most important item) is light compared to the map compilation.

Mr. Swiney, with Babu Maya Das Puri and 8 traversers, carried on the traverse work in the Pákpattan tahsil, Montgomery district. On its completion at the end of December ten traversers were employed on the traverses for the riverain boundary survey along the Sutlej, Chenab and Indus.

Mr. Greiff, with 11 Sub-Surveyors, commenced the field revision in the Gugera and Dipálpur tahsils of Montgomery district, and on their completion moved into the Chunián tahsil, Lahore district.

Mr. French, with 4 Sub-Surveyors, was employed on traverse and plotting work for the Simla Estate boundary survey and this was continued with scarcely more than a week's interruption throughout the field season, thanks to an abnormally mild winter. During the recess a commencement was made of the checking in the field, on large plane-tables, of the detail plotted on the sheets from the traverse work. On the 9th April 1902 towards the close of the field season, Lieutenants Thomas, R.E., and Thuillier, I.A., were attached to the party for a course of plane-tabling in the hills, and were employed until the 6th August on the 2-inch survey of Balsan State. Four Sub-Surveyors were also employed on completing the areas remaining for survey in sheets 333 and 334.

As the work of compilation of 2-inch field sections from the *patwaris' 'musavis,'* and the checking of the same in the field was new to the party, some account may here be given of the experience gained in these two items of the programme, as carried out under Messrs. Robert and Greiff. The traverse work in the Gugera and Dipálpur tahsils carried out in the preceding field season, as a basis for map compilation and the preparation of the 2-inch sheets from the *patwaris' 'musavis'* has been fully described in the last Annual Report of the Punjab Traverse detachment. The work allotted during the recess of 1901 and field season, 1901-02, to this party was very similar. On the abolition of No. 1 party in 1889-90 seven districts had been traversed by that party the settlement was carried out in these districts during the following eight or nine years and the *patwaris'* maps were based (on the square system) on the trijunctions previously picked up by the traversers of No. 1 party. The seven districts so available for map compilation and revision were:—

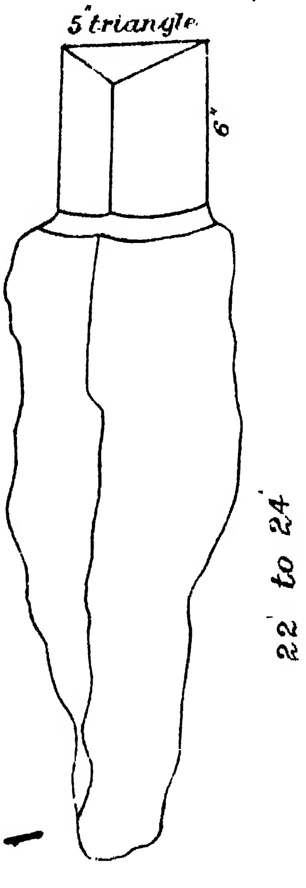
Lahore.	Siálkot.
Amritsar.	Gujrát.
Gurdáspur.	Gujránwála.

Shahpur (plains portion).

In addition to the forty-four 2-inch sections prepared by the Punjab Traverse Detachment in Gugera and Dipálpur tahsils of Montgomery, the map compilation and revision in the field of as much as possible of the Lahore district was allotted to the party. The traverse data were obtained from Lahore, corners of graticules of the 2-inch sections were computed from the origin of the district traverses, and at the same time the *patwaris' 'musavis'* were obtained from the Deputy Commissioner, Lahore. The work of pentagraphing these down

was continued '*pari passu*' with the projection and plotting of the 2-inch sheets. But a difficulty soon presented itself as on attempting to fit the 2-inch reductions of the '*musavis*' on to the field sheets, they would not at first fit at all between trijunctions. It was then discovered that there were 2 '*karms*' or standards of measurement adopted by the *patwaris*' in the Lahore district, that in the Bári Doáb being the '*karm*' of 5 feet and in the Rachna Doáb of 5 feet 6 inches. This of course made the scale of the *patwaris*' maps (at 40 *karms* to the inch) 26·4 inches to the mile and 24 inches to the mile, respectively, in the two Doabs. It was found that almost all the village reductions fitted well, those at all doubtful being omitted from the field sheets with a view to their complete resurvey in the field on the 2-inch scale.

The traverse work in the Pákpattan tahsil was carried out on the ordinary lines and under the usual rules. Complete village boundaries were not traversed, only the trijunctions and village base-line stones being picked up by the traversers in short sufficient data being secured on which to 'hang' the 2-inch reductions of the *patwaris*' '*musavis*.' The traverses for the riverain boundary survey were run on either high bank at a distance which rendered them safe from the effects of water action. These traverses picked up all trijunctions and base-line stones of the villages through which they ran, and dressed stones of the pattern shown were embedded on either side of trijunctions or base line stones to serve as additional fixed points for the picking up and relaying of any village trijunctions or other fixed district boundary mark lying in the river which might at any subsequent period be washed away. These stones were obtained from Chiniot at a cost of 12 annas each, railed to Montgomery, and thence distributed along the river banks by camels. In all 852 were embedded. It has been decided to discontinue the embedding of any more stones in these traverses, as it is considered that the base line stones and trijunctions furnish sufficient fixed points from which lost marks can at any future time be relaid. After these main traverses have been plotted on the 4-inch scale, the corrected '*musavis*' of the villages along either bank, portions of whose boundaries constitute the district boundary in the river bed, are reduced by pentagraph to the 4-inch scale, their trijunctions and base-lines being fitted to the main traverses, and thus a map of the river bed is obtained showing the district boundary therein.



IV. Composition of Detachments and average out-turn per mensem.

The detachment employed on the map compilation, *i.e.*, reduction of '*musavis*,' inking in thereof, and fitting together on 2-inch sheets projected and plotted from the traverse data of No. 1 party, consisted of:—

Mr. W. Robert,
2 Draftsmen,
3 Sub-Surveyors,
2 Apprentices.

The Chunián tahsil of Lahore district was first taken up. This comprises an area of 1,200 square miles and progress at first was slow, the men being new to the work. Too much detail was pentagraphed down from the '*musavis*' with the result that these details when inked in blue on the 2-inch sheets only tended to confuse the men testing and correcting them in the field. Experience was soon gained, and less detail was shown in the reductions of the Lahore tahsil with the result that progress was expedited throughout.

Owing to the expense incurred in the bringing up of some 14,000 to 16,000 '*musavis*' of the Lahore district to Simla, it was decided, with the sanction of the Financial and Settlement Commissioners of the Punjab, to send a small pentagraphing section to Amritsar during the recess with a view to reducing the '*musavis*' of that district (the next allotted for map compilation and revision) on the spot. Accordingly Babu Maya Das Puri, with one draftsman and 5 Apprentices, was temporarily transferred to Amritsar on the 8th June.

The '*musavis*' were reduced and bundles of reductions forwarded weekly to Mr. Robert at Simla who fitted them on to the 2″ sheets projected and plotted (as in the case of the Lahore district) from the old traverse data of No. 1 party.

The total number of villages in the two districts reduced and transferred is 2,685, comprised in 19,539 '*musavis*,' representing an area of 5,210 square miles.

The average rate of pentagraphing may be taken as 1,200 '*musavis*' per man per mensem or between 60 and 70 per working day. The inking in and checking of the reductions on bank post paper is slow work, and it is difficult to give a correct estimate of the average daily rate of this work. The transferring, fitting in, and inking of the reductions on the 2″ sheets is the most laborious work of all. This should be entrusted to an experienced Provincial Officer only, and was carried out entirely by Mr. Robert. His rate of work averaged 9 to 12 villages a day but this rate depends on the size of the villages to be transferred and the amount of detail therein. It takes a good draftsman 6 to 7 days to ink in (village boundaries in black, and detail in blue) a full 2″ sheet of 64 square miles.

The detachment for testing the 2″ sheets in the field and inserting thereon topographical details consisted of Mr. Greiff and eleven Sub-Surveyors.

This detachment completed the map revision of the Gugera and Dipâlpur tahsils of Montgomery and of the Chuniân tahsil, Lahore district, between the 15th November 1901 and the 20th April 1902.

The aggregate area amounted to 3,000 square miles, which gives an average rate of 54½ square miles per man per month. This is small and is due to initial want of experience on the sub-surveyor's part as to the best methods to be adopted. The men had previously only been accustomed to rigorous planetabling on the 4-inch, 2-inch and 1-inch scales in the hills, from numerous well fixed triangulated points, and the absence of the familiar hill-pole, flag, or brush left them at first in somewhat of a dilemma. But with one or two exceptions they quickly grasped the altered conditions, and found that a fixing near a well, or within a foot or two of a trijunction pillar, was sufficient. Moreover during last field season all the village boundaries were tested on the ground. In future this will not be done, all boundaries being accepted as correct when they fit in between trijunctions, and field work in consequence should be much accelerated. In fact an average monthly outturn per man of 80 to 100 square miles may be looked for in the future.

This is too sanguine. Major Bythell subsequently writes to me on 19th March 1903 as follows:
"My estimate is an average of one p.t. section (2″) or 64 square miles per man per mensem. Some will do more (75-80 square miles) but some will not."
J. M. S.,—12-5-03.

As a rule the planetable was set up at either a base line stone or trijunction (always a point picked up by the traverse) and by flagging surrounding trijunctions, cutting in such wells as were to be shown and generally letting the planetable do its work the details were fully checked. Village sites as a rule had to be surveyed afresh, and the omissions most frequently found were the above, the omission of topographical features ' such as nalas, roads, mile-stones, bridges and culverts, and the true course of *rajbahas* and water channels. The work of the Sub-Surveyors was tested by the Assistant and Officer in charge by chain '*partal*' lines and in '*Situ*' fixings, and with the exception of those villages whose reductions would not fit (always due to errors in chain measurements on the *patwaris*' part) the work generally was found to be good and accurate.

W. J. BYTHELL, MAJOR, R.E.

C. I. C. P. O.—No. 834 S. G.—11-4-1904.—250.—J. W. G.